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Technical Report 143

FOREST BIRD INVENTORY OF THE KAHUKU UNIT OF HAWAI`I VOLCANOES NATIONAL PARK

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The Kahuku Unit of the Hawai`i Volcanoes National Park (HAVO) was surveyed for native and non-native birds from January to September of 2005. Bird habitat comprised of forest, woodland, and grassland was divided into five separate regions, and these were surveyed with variable circular plot count methodology to generate estimates of abundance and occurrence. Sampling coverage was more intensive (i.e. several times more count transects and stations) than in past surveys, for more accurate estimates of range and population size. In addition to point counts, we recorded incidental observations to supplement the survey. Ten native and 14 non-native bird species were detected within the region. The most abundant and widespread native forest birds observed were the `Ōma`o (*Myadestes obscurus*), Hawai`i `Amakihi (*Hemignathus virens virens*), `I`iwi (*Vestiaria coccinea*), and `Apapane (*Himatione sanguinea sanguinea*). The second largest populations of three endangered forest bird species in Hawai`i—`Akiapōlā`au (*Hemignathus munroi*), Hawai`i `Ākepa (*Loxops coccineus*), and Hawai`i Creeper (*Oreomystis mana*)—were centered in the Ka`ū Forest Reserve and extended into the Kahuku Unit. The detections within the boundaries of the unit now add these endangered species to HAVO. The Hawai`i `Elepaio (*Chasiempis sandwichensis*) shows evidence of a regional population decline. The two native species that use habitat other than forest—Hawaiian Hawk (*Buteo solitarius*) and Pacific Golden-Plover (*Pluvialis fulva*)—were rarely detected in the study areas. The Japanese White-eye (*Zosterops japonicus*) and Northern Cardinal (*Cardinalis cardinalis*) were the most abundant non-native species. The remaining non-native species were uncommon to rare and were restricted to either the dry leeward or wetter windward sides of the Kahuku Unit.

INTRODUCTION

With the acquisition of the 47,350 ha Kahuku Unit in 2003, the Hawai`i Volcanoes National Park nearly doubled in size and took on the exceptional challenge of managing a large expanse of highly diverse native habitats. The unit extends from about 3,800 m elevation down the south flank of Mauna Loa to about 600 m and consists mostly of exposed lava terrain to about 2,200 m (Figure 1). However, the Kahuku Unit (hereafter Kahuku) also contains tracts of native forest and woodland, and perhaps most importantly, borders several areas managed for the conservation of biological resources: the Ka`ū and Kapāpala Forest Reserves and the Manukā and Kīpāhoehoe Natural Area Reserves administered by the State of Hawai`i Department of Land and Natural Resources, Division of Forestry and Wildlife, and the Kona Hema Preserve managed by The Nature Conservancy. Together, Kahuku and the adjoining areas harbor habitat critically important to native bird populations, and many of the island's other indigenous, endemic, and endangered flora and fauna.

Over the past century, native bird species in Hawai`i have suffered dramatic declines attributed to habitat destruction, introduced predators, and introduced diseases (Scott *et al.* 1986). However, much of the bird habitat in Kahuku is situated above elevations at which avian diseases impact native birds, and these habitats are important refugia. The

forested areas historically managed for cattle also have great potential for restoration and the reestablishment of native bird populations, and they currently supply `ōhi`a (*Metrosideros polymorpha*) nectar to several species of honeycreepers.

The Hawai`i Forest Bird Survey (HFBS) in 1976 (Ka`ū) and 1978 (Kona) covered portions of Kahuku, and the results from these surveys provided regional population estimates on Hawaiian forest bird species (Scott *et al.* 1986). At that time, portions of Kahuku were identified as harboring important populations of three endangered forest bird species: `Akiapōlā`au (*Hemignathus munroi*), Hawai`i `Ākepa (*Loxops coccineus*), and Hawai`i Creeper (*Oreomystis mana*). However, the population estimates and range maps are now out-dated as some of the surveyed area has undergone habitat change and bird populations show evidence of change in size and distribution.

In 1998, Congress approved the National Park Omnibus Management Act to support the development of natural resource management planning for National Parks. In response, the National Park Service created the Inventory and Monitoring Program (I&M) to acquire the data needed to support effective management and protection of the diversity and integrity of the native habitats located on park lands. Towards this end, biologists have carried out surveys of native and non-native bird species within and adjacent to the boundaries of Kahuku. The scope of the surveys was greatly increased over past forest bird surveys; approximately three times as many transects and stations were counted to give more accurate estimates of range and population size. This report is the result of a cooperative agreement between the Pacific Cooperative Studies Unit (University of Hawaii at Manoa and the National Park Service with the participation of the Hawai`i Forest Bird Interagency Database Project at the USGS Pacific Island Ecosystems Research Center (PIERC). The report presents an analysis of the occurrence and abundance of bird species in the park's new addition. A companion study of the distribution, population size and trends in the density of forest birds in the Ka`ū region is currently in preparation (Gorresen *et al.* In prep.).

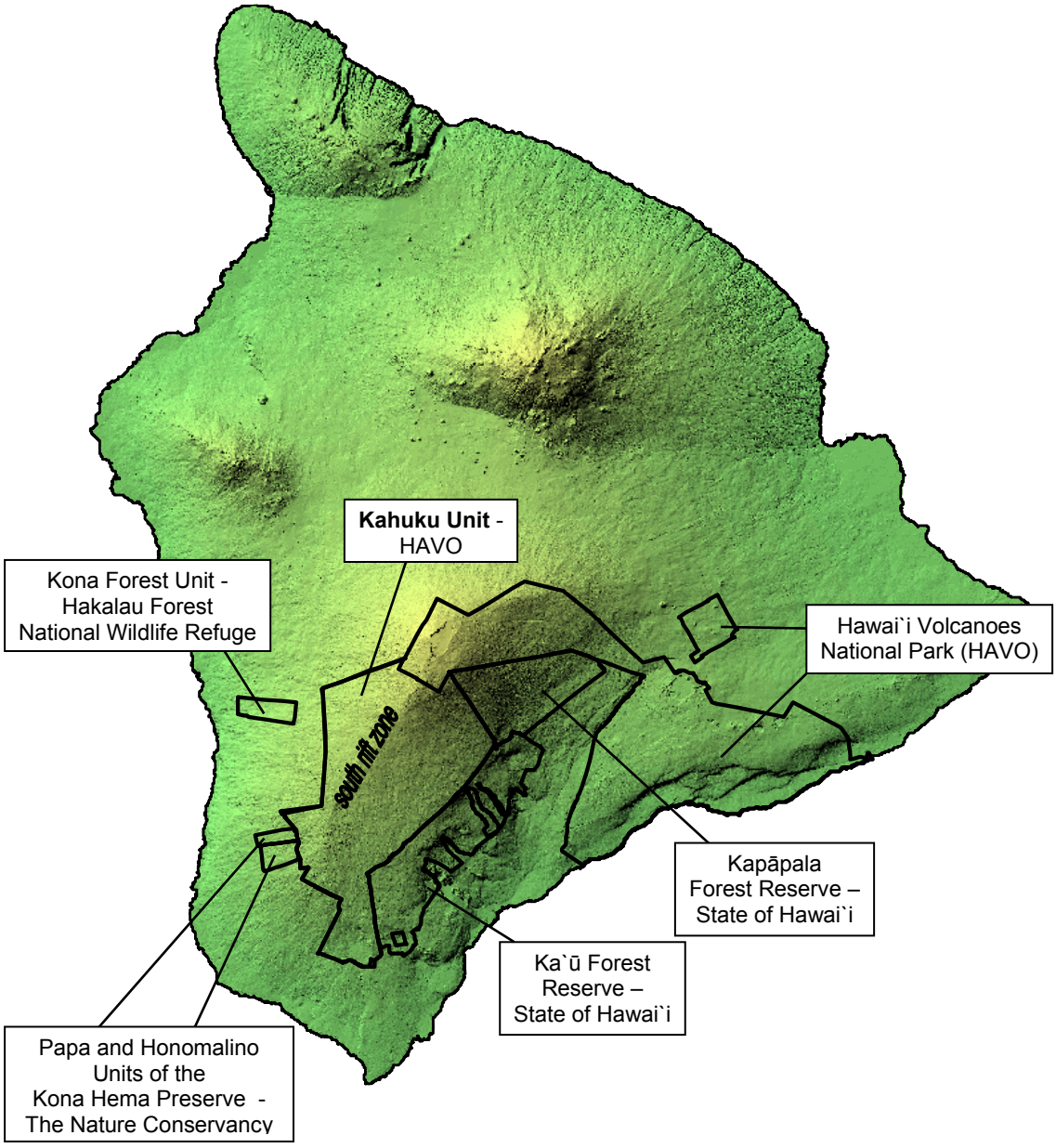

Figure 1. Hawai`i Island land ownership boundaries addressed in the 2005 Kahuku study area.

METHODS

Digital airborne and satellite imagery and vegetation maps (Jacobi 1989) were examined to locate bird habitat within Kahuku and to determine the extent of areas to be surveyed. Five separate regions of forest and woodland bird habitat (equivalent to the "montane wet forest" and "montane moist forest and parkland" vegetation types defined in detail by Cuddihy and Stone [1990]) were distinguished within Kahuku: 1) Ka`ū, 2) South Flank, 3) Honomalino, 4) Papa, 5) and Northwest (Figure 2). Parallel transects spaced between 400 m to 1.5 km apart were established throughout each of the five study areas. This placement was determined by both the size of the study area and sampling effort required to detect rare species. Survey stations were located at 200 m intervals along each transect.

Surveys were conducted using variable circular plot (VCP) count methodology (Reynolds *et al.* 1980). VCP counts are a form of distance sampling used to correct abundance estimates for individuals that go undetected as a function of the distance between an observer and birds. VCP surveys were conducted from January through April 2005 in four study areas and during September 2005 in a fifth study area (Table 1). Five different observers were trained in bird species detection, and they were calibrated for distance estimation prior to conducting surveys. Observers recorded the identity of species and distances to all birds seen or heard during an eight minute count period. Counts were carried out from sunrise to 11:00 AM. A total of 845 stations on 45 transects were surveyed.

VCP is not amenable to the survey of certain species (i.e., raptors, galliform birds, very rare birds) where many birds may remain undetected; therefore, it is likely that the species actually was more widely distributed and present at higher densities in forest and woodland habitat than the results of the survey indicate.

Table 1. Station information for the 2005 Kahuku Forest Bird Inventory, Hawai`i Volcanoes National Park.

Area	Transects	Stations	Dates Surveyed
Ka`ū	25	470	9 January – 23 March
South Flank	3	121	19 – 23 February
Honomalino	8	181	6 – 29 April
Papa	3	18	30 April
Northwest	6	55	25 – 28 September

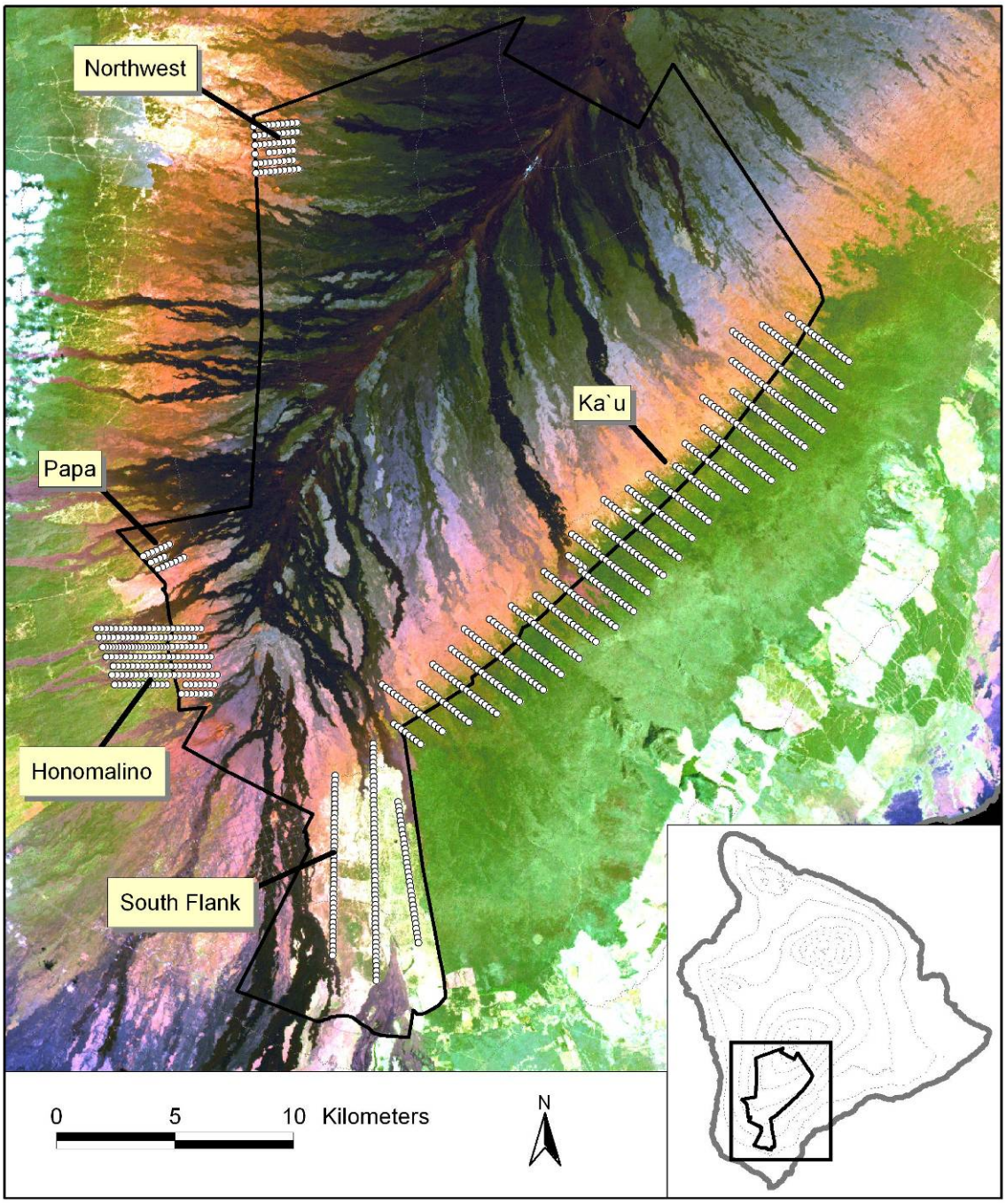

Figure 2. Study areas and survey transects established within and adjacent to Kahuku Unit of Hawai`i Volcanoes National Park (black polygon). Figure background shows general landcover types: green – forest; pink/brown – woodland; white – pasture; blue and black – lava. The image is a synthetic natural color image derived from Landsat ETM bands 1-5 and 7.

Study Areas

Ka`ū

At 9,557 ha, Ka`ū was the largest of the five study areas. It is located on the eastern side of the South Rift Zone on Mauna Loa (Figure 2). The vegetation is comprised primarily of dry sub-alpine `ōhi`a woodland and mature mesic and wet `ōhi`a and koa (*Acacia koa*) forest (Figure 3a and 3b). The study area encompassed about 3,360 ha of the Kahuku Unit and an adjacent 6,197 ha in the Ka`ū Forest Reserve (Figure 1). The inclusion of the forest reserve permitted the survey to extend from tree line down to 1,500 m elevation and thereby generate population estimates for the greater part of the range of `Akiapōlā`au, Hawai`i `Ākepa, and Hawai`i Creeper in this region. Four-hundred and seventy stations were established on 25 transects spaced one kilometer apart.

South Flank

The 3,250-ha South Flank study area, located in the southern portion of Kahuku, lies just east of the South Rift Zone on Mauna Loa (Figure 2). This area has been primarily used for cattle ranching over the past 150 years and was one of the initial introduction sites of mouflon sheep (*Ovis gmelini musimon*) on Hawai`i in the 1960s (Hess *et al*. 2006). Consequently, canopy cover and understory composition has been considerably altered from its original condition as mesic and wet koa-`ōhi`a forest (Figure 4a). Currently, the area consists of open pasture with isolated trees and small stands of native forest. One hundred and twenty-one stations were established along three transects spaced one to 1.5 km apart, and extended from the tree line at 1,500 m to 730 m elevation.

Honomalino

The 850 ha Honomalino study area is located on the western side of the South Rift Zone on Mauna Loa (Figure 2). The study area includes 310 ha within Kahuku and a contiguous 540 ha area of forested land managed by The Nature Conservancy. We were unable to obtain access on privately owned land adjacent to the study area. The vegetation extends down from dry sub-alpine `ōhi`a woodland to mesic koa-`ōhi`a montane forest; several lava flows fragment the habitat and form kipukas in the area. Eight transects spaced at 400 m intervals, and consisting of 181 stations, were situated between 1,770 m and 1,560 m.

Papa

The Papa study area is located about 2.5 km north of Honomalino on the western side of the South Rift Zone on Mauna Loa (Figure 2). At 95 ha, it was the smallest of the five areas surveyed. The vegetation is comprised of sub-alpine `ōhi`a woodland and a small amount of `ōhi`a forest, with both habitats being fragmented by several lava flows. We were unable to gain access to the forested land below and adjacent to Kahuku. A total of 18 stations were established along three transects spaced 400 m apart, and extended from the tree line at 1,700 m down to 730 m.

Northwest

The 850-ha study area is located in the northwest corner of Kahuku and west of the South Rift Zone on Mauna Loa (Figure 2). The dry sub-alpine woodland vegetation is comprised of `ōhi`a, māmane (*Sophora chrysophylla*) and naio (*Myoporum*

sandwicensis) trees, and the kipuka-structure is more pronounced than that at Honomalino and Papa (Figure 4b). The woodland lies upslope from privately owned land and is only five kilometers from the Kona Forest Unit of Hakalau Forest Wildlife Refuge, an important habitat for endangered forest birds (Figure 1). Six transects spaced at 400 m intervals, and with a total of 55 stations, were situated between tree line at 2,440 m and 1,830 m elevation.

a)

b)

Figure 3. a) Open `ōhi`a woodland near tree line, and b) mature montane `ōhi`a forest in the Ka`ū study area of the Kahuku Unit, Hawai`i Volcanoes National Park.

a)

b)

Figure 4. a) Forested pasture in the South Flank study area, and b) `ōhi`a-māmane-naio sub-alpine woodland in the Northwest study area of the Kahuku Unit, Hawai`i Volcanoes National Park.

Data Analysis

VCP count data were entered in the database-compatible Avian Monitoring Entry Form Version 2.1 developed by the Hawaii Forest Bird Interagency Database Project at the USGS Pacific Island Ecosystems Research Center. The program Distance Version 4.1 (Thomas *et al.* 2003) was used to prepare count data for analyses, to develop distance-based models of bird detection probabilities and the area effectively sampled for each species, and to calculate bird densities (bird/ha). Observations from bird surveys conducted between January and September in the Ka`ū survey region (1976, 1993, 2002 and 2005) were pooled for modeling purposes following methods described by Buckland *et al.* (2001). Bird counts were initially examined to derive truncation distances for excluding very distant and unreliable observations and to avoid double-counting birds. Data were truncated at the point where the detection probability was approximately 0.10 (i.e., corresponding to the most distant observations at the "tail" of the data distribution). A detection function was fit to the remaining bird observations following the model selection methods described by Buckland *et al.* (2001, 2004), Burnham and Anderson (2002) and Thomas *et al.* (2003). Model selection was limited to half-normal and hazard-rate detection functions with an expansion series of two orders. These models are most appropriate for VCP counts and allow for the correction of the relative effects upon pooled bird detections of the following covariates: observer, time of day, cloud cover, rain, wind, gust, year, and month. Histograms of the count data and the detection function were plotted, and the fit of the function was examined. If necessary, distant observations were further truncated to improve the fit of the detection function. Models with varying combinations of covariates were compared to identify the best fit of detection function and count data. Selection of the final model for each species was based on the lowest Akaike's Information Criterion score. The final models developed for each species, including covariates, truncation distances and area effectively sampled, are detailed in Appendix A.

Mean density variance was obtained by a bootstrap method in Distance (Buckland *et al.* 2001) that involves taking a random sample with replacement of the detections observed at stations in each study area, and by re-running the analysis to estimates densities for each of 999 iterations. The 95% confidence limits for the mean annual density estimate was calculated as the 5^{th} and 95^{th} percentiles of the bootstrapped values.

Population sizes for the endangered species (the estimated total number of birds in an area of size A) were calculated as mean density multiplied by the area of the species' distribution. Variance and confidence limits were calculated in the same manner as for population size.

We updated the bird species list for HAVO using the 2005 Kahuku bird survey data according to guidelines in the NPS Data Dictionary for Users: Field and Value Definitions (Wotawa 2004). Species lists are created from NPSpecies, the National Park Service biodiversity database.

RESULTS

A total of ten native and 14 non-native bird species was detected during VCP surveys within the five Kahuku study areas (Table 2). The native species included: Hawaiian Hawk (`Io) (*Buteo solitarius*), Pacific Golden-Plover (Kōlea) (*Pluvialis fulva*), Hawai`i `Elepaio (*Chasiempis sandwichensis*), `Ōma`o (*Myadestes obscurus*), Hawai`i `Amakihi (*Hemignathus virens virens*), `Akiapōlā`au (*Hemignathus munroi*), Hawai`i Creeper (*Oreomystis mana*), Hawai`i `Ākepa (*Loxops coccineus coccineus*), `I`iwi (*Vestiaria coccinea*), and `Apapane (*Himatione sanguinea sanguinea*).

The non-native species included: Erckel's Francolin (*Francolinus erckelii*), Kalij Pheasant (*Lophura leucomelanos*), Wild Turkey (*Meleagris gallopavo*), Spotted Dove (*Streptopelia chinensis*), Zebra Dove (*Geopelia striata*), (Eurasian) Sky Lark (*Alauda arvensis*), Hwamei (*Garrulax canorus*), Red-billed Leiothrix (*Leiothrix lutea*), Japanese White-eye (*Zosterops japonicus*), Common Myna (*Acridotheres tristis*), Saffron Finch (*Sicalis flaveola*), Northern Cardinal (*Cardinalis cardinalis*), House Finch (*Carpodacus mexicanus*), and Yellow-fronted Canary (*Serinus mozambicus*).

In addition, we recorded five bird species while traveling through or near the study areas that were not detected during the VCP surveys: Hawaiian Goose (Nēnē; *Branta sandvicensis*), Chukar (*Alectoris chukar*), Common Peafowl (*Pavo cristatus*), Rock Dove (*Columba livia*), and Yellow-billed Cardinal (*Paroria capitata*). All species described are included in the species list for the Kahuku Unit of HAVO (Appendix B).

Several species are notable for not having been detected during the Kahuku survey but whose occurrences were established during the 1976 and 1978 Hawai`i Forest Bird Surveys (Scott *et al.* 1986). These species include: Black Francolin (*Francolinus francolinus*) in the dry open upland habitats of the leeward study areas; Japanese Quail (*Coturnix japonica*) in the dry open upland habitats at the southern portion of the Ka`ū study area; Ring-necked Pheasant (*Phasianus colchicus*) in all vegetated habitats throughout Kahuku; and California Quail (*Callipepla califonica*) and Nutmeg Mannikin (*Lonchura punctulata*) in the dry open upland habitats of the South Flank and leeward study areas. Another absent species, the Japanese Bush-Warbler (*Cettia diaphone*), is now established in the lower elevations of the Ka`ū Forest Reserve (Jeffrey Foster, pers. comm.). Bush-Warblers are rapidly expanding their range on the Big Island and are expected to be a common species at Kahuku in future years.

Total counts of each species across all five study areas ranged from a single detection of a Saffron Finch to over 4,000 detections of `Apapane (Table 2). In general, the least common native species were the Hawaiian Hawk and Pacific Golden-Plover in open habitats and the `Akiapōlā`au and Hawai`i Creeper in forested habitats. Hawai`i `Amakihi and `Apapane were the most abundant native species detected. As in many areas throughout the state, the Japanese White-eye and Northern Cardinal were the most abundant non-native species in Kahuku.

The minimum number of detections for adequate estimation of density was met for eight native and ten non-native species (Table 3). Density values ranged three across orders of

magnitude from the very rare (<0.001 birds/ha for Sky Lark) to very abundant (about eight birds/ha for `Apapane).

Table 2. Abundance and occurrence of species detected during the 2005 Kahuku Forest Bird Inventory. Symbols "#", "occ" and "%" indicate the number of birds detected, and the number and percent of stations (stns) surveyed at which the species occurred within each study area. Native bird species are highlighted in bold. Empty cells indicate that no detections were recorded during VCP surveys.

	Ka`ū (474 stns)			South Flank (121 stns)			Honomalino (166 stns)			Papa (18 stns)			Northwest (55 stns)		
Species	#	occ	%	#	occ	%	#	occ	%	#	occ	%	#	occ	%
Hawaiian Hawk (`Io)	8	7	2	1	1	<1							1	1	2
Erckel's Francolin	10	8	2	48	36	30	64	52	31	4	4	22	44	31	56
Kalij Pheasant	21	10	2										1	1	2
Wild Turkey	10	8	2	10	6	5	13	10	6	3	2	11	1	1	2
Pacific Golden-Plover	6	6	1	6	3	3							5	2	4
Spotted Dove				22	14	14							3	3	6
Zebra Dove				12	8	7									
Hawai`i `Elepaio	38	29	6				29	21	13				3	2	4
(Eurasian) Sky Lark	1	1	<1				5	5	3				25	16	29
`Ōma`o	733	335	71	47	29	24									
Hwamei				3	3	3									
Red-billed Leiothrix	154	83	18												
Japanese White-eye	550	301	64	309	118	98	193	106	64	24	13	72	67	26	47
Common Myna				14	9	7									
Saffron Finch				1	1	<1									
Northern Cardinal	31	24	5	152	79	65	383	150	90	30	11	61	14	10	18
House Finch				84	51	42	143	74	45	9	4	22	45	17	31
Yellow-fronted Canary				18	13	11									
Hawai`i `Amakihi	732	361	76	135	68	56	800	165	99	76	18	100	358	55	100
`Akiapōlā`au	23	17	4												
Hawai`i Creeper	33	23	5												
Hawai`i `Ākepa	90	53	11												
`I`iwi	374	209	44				58	44	27				51	28	51
`Apapane	3061	474	100	151	54	45	601	166	100	56	18	100	231	55	100

Table 3. Density of bird species detected during the 2005 Kahuku Forest Bird Inventory. Density is reported as mean number of birds per hectare (#/ha) with lower and upper 95% confidence interval values. Native bird species are highlighted in bold. Empty cells indicate the species was not detected in the study area (see Table 2). Bird species that were omitted (see Table 2) did not have a sufficient number of detections to develop detection functions used for density estimation.

	Ka`ū (474 stns)			South Flank (121 stns)			Honomalino (166 stns)			Papa (18 stns)			Northwest (55 stns)		
Species	#/ha	lower	upper	#/ha	lower	upper	#/ha	lower	upper	#/ha	lower	upper	#/ha	lower	upper
Erckel's Francolin	0.006	0.003	0.013	0.108	0.076	0.154	0.097	0.069	0.136	0.064	0.026	0.161	0.168	0.112	0.251
Kalij Pheasant	0.091	0.035	0.241										0.012	0.004	0.036
Wild Turkey	0.006	0.003	0.013	0.023	0.008	0.072	0.230	0.010	0.053	0.038	0.013	0.109	0.002	<0.001	0.019
Spotted Dove				0.040	0.023	0.070							0.040	<0.001	0.179
Hawai`i `Elepaio	0.144	0.075	0.276				0.320	0.076	1.349				0.097	0.013	0.700
(Eurasian) Sky Lark	<0.001	<0.001	0.021				0.009	0.002	0.036				0.115	0.051	0.259
`Ōma`o	1.025	0.904	1.162	0.330	0.260	0.461									
Red-billed Leiothrix	0.330	0.241	0.453												
Japanese White-eye	2.358	2.019	2.755	3.253	2.849	3.714	1.911	1.599	2.284	2.857	1.963	4.158	1.881	1.268	2.789
Northern Cardinal	0.026	0.014	0.050	0.485	0.392	0.559	0.829	0.613	1.122	0.576	0.334	0.994	0.095	0.039	0.230
House Finch				0.597	0.402	0.887	0.735	0.541	0.998	0.557	0.145	2.141	0.530	0.247	1.136
Yellow-fronted Canary				0.168	0.020	1.402									
Hawai`i `Amakihi	1.647	1.401	1.936	0.832	0.650	1.065	4.528	4.069	5.038	4.714	3.278	6.778	4.723	3.984	5.599
`Akiapōlā`au	0.193	0.111	0.336												
Hawai`i Creeper	0.353	0.181	0.692												
Hawai`i `Ākepa	0.321	0.168	0.613												
`I`iwi	0.885	0.729	1.075				0.393	0.288	0.537				0.605	0.368	0.995
`Apapane	7.982	6.982	9.125	0.924	0.663	1.286	3.481	3.044	3.982	3.635	2.174	4.867	2.800	2.148	3.650

Native Species Accounts

Hawaiian Goose (Nēnē)

The Hawaiian Goose was only incidentally observed while traveling through the South Flank study area. Four individuals were seen at a catchment pond at the edge of mesic koa-`ōhi`a forest kipuka and exposed lava terrain at 1,890 m elevation. Kahuku was an important former release site for this species.

Hawaiian Hawk (`Io)

The Hawaiian Hawk was only observed within the Ka`ū, South Flank and Northwest study areas (Table 2; Figure 5). Occurrence was low (≤ 2% of stations surveyed), and the number of detections were too low to estimate densities. Detections occurred within a range of habitats including mesic and wet koa-`ōhi`a forest, `ōhi`a-māmane-naio sub-alpine woodland, and open pasture with remnant stands of native forest. However, the Hawaiian hawk is not amenable to VCP surveys (i.e., call playbacks are the method of choice; e.g., see Klavitter *et al.* 2003), and it is likely that the species was more widespread than the study results indicate.

Pacific Golden-Plover (Kōlea)

The Pacific Golden-Plover was only observed within the Ka`ū, South Flank and Northwest study areas (Table 2; Figure 6). Occurrence was low (≤ 4% of stations surveyed), and the number of detections were too few to estimate densities. The species was observed within the fairly open habitats of `ōhi`a-māmane-naio sub-alpine woodland and open pasture.

Hawai`i `Elepaio

Hawai`i `Elepaio were only observed within the Ka`ū, Honomalino and Northwest study areas (Table 2; Figure 7). With the exception of three individuals in the Northwest study area, all detections occurred outside of Kahuku proper. Whereas the detections at Northwest occurred in `ōhi`a-māmane-naio sub-alpine woodland, `Elepaio only occurred within the mesic koa-`ōhi`a forest at Honomalino and was not found in the woodland directly upslope. `Elepaio in Ka`ū only occurred within wet koa-`ōhi`a forest and were also not found in the woodland. Mean densities were estimated at 0.14, 0.32, and 0.10 birds/ha in the Ka`ū, Honomalino, and Northwest study areas, respectively (Table 3).

It is notable that `Elepaio observations in the Ka`ū study area were entirely limited to the northern half of the forest reserve below 1,800 m elevation. Although, much of the south Ka`ū forest would appear to be suitable habitat, it harbors few, if any, `Elepaio. Moreover, a comparison of observations made during the 2005 survey to that of the 1976 Hawai`i Forest Bird Survey (HFBS) appears to indicate that frequency of occurrence has declined sharply throughout the larger Ka`ū region, and the southern portion of the species' range has contracted northeastward by at least five km (Gorresen *et al.* In prep.). In addition, the current density observed in central Ka`ū above 1,500 m (about 0.3 birds/ha) is significantly less than that recorded during 1976 HFBS (about 0.6 birds/ha).

Some of the differences in occurrence and density between years may be attributable to differences in detection probabilities among seasons (i.e., greater in the summer and lower in the spring when the 1976 and 2005 surveys were conducted, respectively). However, the same general downward trends in `Elepaio occurrence and density are evident in upper and mid-elevation habitat in other central windward areas of Hawai`i Island (specifically, `Ōla`a and East Rift; Gorresen *et al.* 2005).

Most `Elepaio records in Ka`ū are now restricted to areas in which koa is present. However, the importance of koa as a prey substrate in the foraging ecology of `Elepaio in this region is not known, and koa has been shown to be used less frequently for foraging than expected on basis of their abundance in Hakalau Forest National Wildlife Refuge (VanderWerf 1998).

`Ōma`o

`Ōma`o were detected in forest habitat throughout the Ka`ū study area, with a few additional observations in the upper elevation woodland (Table 2; Figure 8). `Ōma`o also occurred in a few areas of the forested pasture between 1,040 and 1,580 m elevation at the South Flank study area. Mean densities of 1.03 and 0.33 birds/ha were estimated for Ka`ū and South Flank, respectively (Table 3). There were no detections of `Ōma`o in the three study areas on leeward Hawai`i Island. More specifically, `Ōma`o were absent from areas (Honomalino and Papa) where a few birds were observed during the 1979 HFBS. However, the 2005 Kahuku survey transects did not extend much above treeline in these areas and may have missed a sparsely distributed `Ōma`o population in the upper elevation shrubland.

Despite the possibility of low numbers of `Ōma`o in open sub-alpine `ōhi`a shrubland (Scott *et al* 1986), the arid and exposed landcover extending along the South Rift Zone may act as a barrier to the reestablishment of the species into the leeward side of the island. `Ōma`o are major seed dispersers (Wakelee and Fancy 1999), and the translocation and establishment of populations in leeward forests where they once occurred could expedite recovery of native forests that have been altered by cattle ranching.

Hawai`i `Amakihi

Hawai`i `Amakihi were found at all five study areas (Figure 9), and were the most abundant bird species in all areas except Ka`ū and the South Bank (Table 2). The species was observed at comparatively low densities in the more mesic and wet habitats of the windward sites: 1.65 birds/ha at Ka`ū and 0.83 birds/ha at South Flank (Table 3). However, the leeward study areas had fairly high bird densities: 4.53 birds/ha at Honomalino, 4.71 birds/ha at Papa, and 4.72 birds/ha at Northwest. The high densities of Hawai`i `Amakihi observed in leeward Kahuku are comparable to those found at other sites throughout the Kona and Hualālai regions of Hawai`i Island (Camp *et al.* In prep.).

Hawai`i `Amakihi were fairly ubiquitous in the open pasture with small stands of trees at South Flank, an observation in keeping with their generalist behavior (Lindsey *et al.* 1998). The species also was recorded at fairly low elevations in this study area

(minimum 725 m), a pattern similar to that observed in dry forest, woodland and shrubland in the Kīlauea section of Hawai`i Volcanoes National Park (Turner *et al.* 2007) and low elevations elsewhere in Puna (Woodworth *et al.* 2005).

`Akiapōlā`au

`Akiapōlā`au were only detected in the northeastern portion of the Ka`ū forest between 1,525 and 1,950 m elevation (Table 2). Two detections were made within the boundaries of Kahuku (Figure 10), and thus the acquisition of the unit adds the species to HAVO. The species was estimated to occur at a mean density of 0.19 birds/ha for the portion of the study area coincident with its 5,555 ha range in Ka`ū (Table 3). Given the above density and range, the population in Ka`ū was estimated at 1,073 birds (95% confidence interval [CI] = 616 – 1,869 birds). This mean density is considerably larger than that of previous studies. The 1976 HFBS yielded a population estimate of 533 (95% CI = 214 – 852) individuals (Scott *et al* 1986). A 1993-1994 survey along many of the same transects resulted in a population estimate of only 44 individuals (95% CI = 0 – 94 birds; Fancy *et al.* 1996).

`Akiapōlā`au have a very low reproductive rate, usually producing one chick per year (Pratt 2001). Therefore, it is not possible for the population to show the magnitude of increase within a decade indicated by the observed 1993-1994 density. The differences among estimates may instead be a reflection of sampling error rather than changes in population size. Unlike other Hawaiian birds, it is difficult to predict the beginning of the breeding season and to target surveys for when `Akiapōlā`au are most vocal. We were fortunate that the Ka`ū population was vocal during our surveys, thereby allowing us to produce a robust population estimate. The very different population estimates demonstrate the need for caution when comparing `Akiapōlā`au density and population estimates over time.

Hawai`i Creeper

Hawai`i Creeper were only detected in the northeastern half of the Ka`ū study area (Table 2; Figure 11). The detections within the boundaries of Kahuku now add the species to HAVO. All observations occurred within forest habitat between 1,525 and 1,950 m. The species was estimated to occur at a mean density of 0.35 birds/ha for the portion of the study area coincident with its 6,418-ha range in Ka`ū (Table 3). Given the above density and range, the population in Ka`ū was estimated at 2,268 birds (95% CI = 1,159 – 4,438 birds).

The above mean population size and density is fairly close to that of the 2,102 $\pm$ 540 birds and 0.24 birds/ha estimated by Scott *et al.* (1986) from the 1976 HFBS. The 2005 mean density is also similar to the 0.27 birds/ha observed in 1993, but is much lower than the 1.23 birds/ha recorded in 2002 (Camp *et al.* In prep.). As with `Akiapōlā`au, the estimates derived from surveying rare species are prone to high levels of uncertainty (Gorresen *et al.* 2005).

Although the Hawai`i Creeper was not observed in the Northwest study area, the species conceivably may be present and further surveys may be warranted. The area surveyed is

only about five km northeast from recent occurrence records of Hawai`i Creeper within the Kona Forest Unit (KFU) of the Hakalau Forest National Wildlife Refuge (HFNWR).

Hawai`i `Ākepa

Hawai`i `Ākepa also were only detected in the northeastern half of the Ka`ū study area (Table 2; Figure 12). The detections within the boundaries of Kahuku now add the species to HAVO. All observations in Ka`ū occurred within forest habitat between 1,550 and 2,200 m elevation. The species was estimated to occur at a mean density of 0.32 birds/ha for the portion of the study area coincident with its 7,958 ha range in Ka`ū (Table 3). Given the above density and range, the population in Ka`ū was estimated at 2,556 birds (95% CI = 1,340 – 4,876 birds). As with Hawai`i Creeper, Hawai`i `Ākepa occur in the KFU and have the potential to be found in the Northwest study area.

We witnessed groups of Hawai`i `Ākepa foraging in sub-alpine woodland in the Ka`ū study area. Our observations support those of Scott *et al.* (1986), in which high densities of this species were also detected in this habitat. Hawai`i `Ākepa forage almost exclusively on insects located in the buds and the new flush of `ōhi`a foliage (Hart 2000). Because the sub-alpine habitat is open and trees are widely spaced, terminal leaf buds are not relegated to the canopy but can extend down to the base of the tree, and this greatly increases the surface area available to foraging `Ākepa (Figure 3a).

Hawai`i `Ākepa are believed to nest exclusively within tree cavities and to require large trees for nesting (Hart 2000). Although suitable nesting trees do not occur in the sub-alpine woodland, potential nesting trees do occur a little more than a kilometer down slope in the mature montane forest. The absence of nesting cavities leads us to believe that the Hawai`i `Ākepa in Ka`ū are perhaps either making daily or seasonal foraging movements more of than one kilometer, or there are individuals in this population that exhibit a different nesting behavior. That is, this population perhaps may build cup nests similar to the Kaua`i `Ākepa or `Akeke`e (*Loxops caeruleirostris*; Lepson and Pratt 1997). Most of our knowledge of Hawai`i `Ākepa biology comes from the windward population in HFNWR, and there is little sub-alpine woodland habitat directly above the mature montane forests of the refuge, perhaps precluding nesting in strata other than mature tree cavities. The Ka`ū population needs further research to determine whether it exhibits foraging and nesting behavior the same or different from that of the Hakalau population.

As with the Hawai`i Creeper, the Northwest study area does have the potential to harbor Hawai`i `Ākepa despite the lack of detections. The area surveyed is only about 5 km northeast from recent occurrence records of Hawai`i `Ākepa within the KFU of the HFNWR.

`I`iwi

`I`iwi were observed in the Ka`ū, Honomalino and Northwest study areas (Table 2; Figure 13). In Ka`ū and Honomalino, nearly all detections were within mesic and wet forest habitat, whereas in Northwest, `I`iwi were recorded in the dry sub-alpine

woodland. Densities in Ka`ū, Honomalino and Northwest were 0.99, 0.39 and 0.61 birds/ha, respectively.

High elevation forest and woodland are extremely important for `I`iwi as this species is very susceptible to introduced diseases that are prevalent in mid and low elevation habitats (Atkinson *et al.* 1995). The presence of `I`iwi in the Northwest study area within dry sub-alpine woodland during September underscores the fact that this species will seasonally migrate to exploit blooms at high elevations. Although this species does make seasonal use of habitat in which avian malaria is present, it is not likely to survive in areas with little or no high elevation habitat, and the integrity of high elevation forests are critically important for `I`iwi.

In July 2005, `I`iwi were incidentally observed in the upper portions of forested pasture in Kahuku. The absence of `I`iwi in this habitat at the time of the VCP surveys may have been the result of seasonal movements rather than a reflection of habitat quality or the presence of avian malaria.

`Apapane

With the exception of the South Flank, `Apapane occurred at all stations in each of five study areas (Table 2; Figure 14). At South Flank, `Apapane were fairly common in the forested pasture above 1,100 m, and there were a few birds detected as low as 820 m. Mean densities were estimated at 7.98 birds/ha in Ka`ū, 0.92 birds/ha in South Flank, 3.48 birds/ha in Honomalino; 3.64 birds/ha in Papa, and 2.80 birds/ha in Northwest (Table 3). `Apapane are currently the most abundant native bird species in Kahuku. Surveys elsewhere have previously reported densities as high as 30 birds/ha in forest habitats on the major Hawaiian islands (Camp *et al.* In prep.).

Although `Apapane are more prevalent at higher elevations, they are still present within forest habitat at mid and lower elevations where disease transmission is likely to occur. The species may be evolving resistance to avian malaria and recolonizing their former range in lowland native habitats, as has been noted in Puna and elsewhere (Woodworth *et al.* 2005).

Non-native Species Accounts

Chukar

Two Chukar were incidentally observed within dry sub-alpine pūkiawe (*Leptecophylla tameiameiae*) shrubland at 1,950 m in the Ka`ū study area. Chukar were notably absent from upland areas such as South Flank and the leeward study areas for which Scott *et al.* (1986) had recorded the species' occurrence.

Erckel's Francolin

Erckel's Francolin was detected in all five study areas, but its occurrence was limited exclusively to the relatively dry and open leeward habitats comprised of `ōhi`a-māmane-naio sub-alpine woodland and open pasture with remnant stands of native forest (Table 2;

Figure 15). The lowest and highest proportions of occupancy were 2% and 56% at Ka`ū and Northwest, respectively. Mean densities were estimated at <0.01 birds/ha in Ka`ū, 0.11 birds/ha in South Flank, 0.10 birds/ha in Honomalino; 0.06 birds/ha in Papa, and 0.17 birds/ha in Northwest (Table 3). The Erckel's Francolin is the most prevalent galliform bird found in dry open habitats.

Kalij Pheasant

Kalij Pheasant occurrence was very low and mostly limited to the wet and mesic forest of Ka`ū (2% of surveyed stations; Table 2; Figure 16), although a single bird was detected in the sub-alpine woodland of the Northwest study area. Mean densities were estimated at 0.09 birds/ha in Ka`ū and 0.01 birds/ha in Northwest (Table 3). However, VCP is not amenable to the survey of the Kalij Pheasant and many birds were likely to have gone undetected; therefore, it is likely that the species actually was more widely distributed and present at higher densities in forest and woodland habitat than the results of the survey indicate. The Kalij Pheasant was the only galliform bird observed in forest habitat.

Common Peafowl

Common Peafowl were incidentally heard calling or were seen below 1,000 m along the eastern South Flank during the late summer breeding season (Thane Pratt and Linda Pratt, pers. comm.). The species appears to be fairly sparsely distributed in the open pasture and edge of forest remnant stands at lower elevations within the study area.

Wild Turkey

Although occurrence was low, Wild Turkeys were recorded in open forest, woodland and grassland habitats at all five study areas (Table 2; Figure 17). The highest incidence of detections were in mesic koa-`ōhi`a forest at Honomalino and Papa (13 observations at 6% of stations surveyed; and three observations at 11% of stations surveyed, respectively). The number of Wild Turkey detections was too low to estimate densities.

Rock Dove

The Rock Dove was incidentally seen in association with lava cavities located in proximity to a residential area (Hawai`i Ocean View Estates) at 850 m elevation along the western edge of the South Flank study area (Linda Pratt, pers. comm.). We suspect the occurrence of Rock Dove in this area to be associated with human settlement.

Spotted Dove

The Spotted Dove was fairly uncommon and only detected at two study areas: South Flank and Northwest (Figure 18). Occurrence and density were 14% and 0.04 birds/ha in the open pasture and forest remnant habitat of South Flank, and 6% and 0.04 birds/ha in the sub-alpine woodland of the Northwest study area (Tables 2 and 3). The occurrence of Spotted Dove at South Flank is likely due to its preference for habitats modified by human activities.

Zebra Dove

The Zebra Dove was only detected in the open pasture and forest remnant habitat at South Flank (Table 2; Figure 19). The species occurred at only 7% of the stations surveyed in the study area, and numbers were too low to estimate density. The species was absent from upland habitats in the leeward study areas at which Scott *et al.* (1986) had recorded moderately low densities. The occurrence of Zebra Dove at South Flank is also likely due to its association with human settlement.

(Eurasian) Sky Lark

Sky Lark were moderately common (29% of stations surveyed and 0.10 birds/ha) in the sub-alpine woodland at Northwest (Tables 2 and 3; Figure 20). A small number were also observed in mesic forest at Honomalino, and a single detection was made in upper elevation woodland at Ka`ū. The species' absence from habitat in the South Flank study area at which it was recorded during the 1978 HFBS (Scott *et al.* 1986) may represent a modest range contraction in the region.

Hwamei

The Hwamei (Melodius Laughing-thrush) was only detected in the lower portions of the open pasture and remnant forest habitat at South Flank (Table 2; Figure 21). A single detection was recorded at each of three stations (3% of the stations surveyed in the study area), and numbers were too low to estimate density. The species' occurrence at South Flank likely represents a range expansion from the low and mid-elevation habitats in southeast Hawai`i Island noted by Scott *et al.* (1986).

Red-billed Leothrix

Restricted exclusively to the mesic and wet forest habitat of Ka`ū, the Red-billed Leothrix was detected at a density of 0.33 birds/ha at 18% of the stations surveyed (Tables 2 and 3; Figure 22). The species was notably absent from upland areas in the South Flank and the leeward study areas where Scott *et al.* (1986) had recorded low to moderately high abundance. It is unknown to what extent this absence is a seasonal occurrence.

Japanese White-eye

The Japanese White-eye was the most abundant and widespread of all non-native birds. The species occurred in all habitats and within all of the five study areas of the Kahuku region (Figure 23). Its occurrence and density was highest in the pasture and forest mosaic at South Flank (98% of stations surveyed and 3.25 birds/ha; Tables 2 and 3). It also was found in high numbers in the forest and woodland of Ka`ū, Honomalino and Papa (64% and 2.36 birds/ha, 64% and 1.91 birds/ha, 72% and 2.86 birds/ha, respectively). It was also fairly common in the woodland at Northwest (47% and 1.88 birds/ha).

Common Myna

The Common Myna was only detected in the lower portions of the open pasture and forest remnant habitat at South Flank (Table 2; Figure 24). The species occurred at only

7% of the stations surveyed in the study area, and numbers were too low to estimate density. The Common Myna was absent from an area of dry open habitat in the upper mid-section of the Ka`ū study area and was also not observed in upland leeward habitats where Scott *et al.* (1986) had recorded the species' occurrence.

Saffron Finch

A single detection of a Saffron Finch was made at the very lowest extent of the open pasture habitat in the South Flank study area (Table 2; Figure 25). Noted by Scott *et al.* (1986) to have spread along the Kona coast since the HFBS, the species has since spread and occupies suitable habitat (lawns and close-cropped pasture) in South Kona and Ka`ū districts.

Yellow-billed Cardinal

The Yellow-billed Cardinal was incidentally seen within open pasture habitat at 600 m in the South Flank study area (Thane Pratt, pers. obs.). The Yellow-billed Cardinal is common on the leeward coast of Hawai`i Island up to about 700m elevation (Hawaii Audubon Society 1997), and in the past ten years the species has spread into Ka`ū District.

Northern Cardinal

The Northern Cardinal was the second-most abundant and widespread non-native bird species. It was recorded in all five study areas and in almost all habitats, although in lesser numbers than the Japanese White-eye (Figure 26). It occurred at a moderately high abundance throughout nearly the entire Honomalino study area (90% of stations surveyed and 0.83 birds/ha; Tables 2 and 3), and was also common in the neighboring Papa and South Flank study areas (61% and 0.58 birds/ha, 65% and 0.49 birds/ha). The species was uncommon in sub-alpine woodland at the lower portion of the Northwest study area (18% and 0.10 birds/ha) and in the mesic woodland and wet forest of Ka`ū (5% and 0.03 birds/ha). Its occurrence in the Ka`ū study area is notable since Scott *et al.* (1986) had not recorded it in the woodland and forest habitat in upper elevations of this region.

House Finch

The House Finch was the third-most common non-native species and was fairly abundant and widespread in all the study areas besides Ka`ū (Tables 2 and 3; Figure 27). It occurred in both the relatively dry and open habitats found in the leeward study areas, which are comprised of sub-alpine woodland and open pasture with remnant forest stands, as well as in the more mesic forest at Honomalino. The species was most abundant in Honomalino (45% of stations surveyed and 0.74 birds/ha) and South Flank (42% and 0.60 birds/ha). The House Finch was absent from the dry upland habitats in the Ka`ū study area at which Scott *et al.* (1986) had recorded the species' occurrence.

Yellow-fronted Canary

The Yellow-fronted Canary was only detected in the open pasture and forest remnant habitat at South Flank, and was recorded as high as about 1,600 m (Table 2; Figure 28). The species occurred at 11% of the stations surveyed in the study area, but numbers were

too low to estimate density. Absent at South Flank during the 1978 HFBS, its occurrence documents a range expansion in the region, where the species is now widespread.

DISCUSSION

The 2005 bird surveys within and adjacent to the Kahuku Unit of HAVO produced current estimates of the distribution, occurrence and density of ten native and 19 non-native forest bird species. Four of the eight native species found in forest habitat remain common and widespread: `Ōma`o, Hawai`i `Amakihi, `I`iwi and `Apapane. Alarmingly, the Hawai`i `Elepaio is very uncommon and shows evidence of a regional population decline in the Ka`ū region. The two native species using habitat other than forest—Hawaiian Hawk (`Io) and Pacific Golden-Plover (Kōlea)—were rarely detected in the study areas. Although fairly uncommon or rare and restricted in range, the populations of the endangered `Akiapōlā`au, Hawai`i `Ākepa and Hawai`i Creeper in the Ka`ū region are the second largest in the state of Hawai`i. Detection of these species in Kahuku now augments the number of species managed by HAVO. All three species are federally listed as endangered (U.S. Fish and Wildlife Service [USFWS] 1967, USFWS 1975, USFWS 1970), and protected under the State of Hawai`i Endangered Species Law (March 22, 1982). The region's habitat is critically important to the long-term survival of `Akiapōlā`au, Hawai`i `Ākepa and Hawai`i Creeper, and will require intensive efforts to restore and protect it from the impacts of ungulate browsing. Additional surveys at Northwest are warranted because the sub-alpine woodland habitat has the potential to support `Akiapōlā`au, Hawai`i `Ākepa and Hawai`i Creeper, and the area is located in close proximity to populations of these endangered species in the Kona Forest Unit of the Hakalau Forest National Wildlife Refuge. A discussion of the threats facing native birds and available management strategies may be found in Banko *et al.* (2001).

The Japanese White-eye, Northern Cardinal and House Finch were the most abundant and widespread of the non-native species. The remaining non-native species were uncommon to rare and restricted to either the dry leeward or wetter windward sides of Kahuku. Five non-native species were notably absent from habitats where they were recorded during the 1976 and 1978 Hawai`i Forest Bird Surveys (Scott *et al.* 1986): Black Francolin, Japanese Quail, Ring-necked Pheasant, California Quail, and Nutmeg Mannikin. The absence of the galliform birds may be due, in part, to these species' elusive and cryptic behavior and the low probability of detecting birds that occur at low abundances during VCP surveys. We are puzzled by past records of Black Francolin at Kahuku, as this species is otherwise absent from Ka`ū District. The most conspicuous apparent loss is that of the Ring-necked Pheasant, even though ample pastureland habitat remains. The species was not likely to have been missed since the study areas were repeatedly visited both by bird and botany crews. Interestingly, the race represented was the Japanese Green Pheasant (*P. c. versicolor*), and this distinctive green-breasted form occupied Kahuku as one of its last strongholds in Hawai`i. These three species of gallinaceous birds may also have declined as a result of competition with the now widespread and common Erckel's Francolin and Kalij Pheasant. The Nutmeg Mannikin may have been missed by the seasonal and "irruptive" nature of the species' movements. Lastly, we expect Japanese Bush-Warblers, a species that has recently moved into low elevation forests in adjacent Ka`ū Forest Reserve, to soon colonize Kahuku.

The survey transects established in the five study areas could serve as a sampling framework for future monitoring of bird population trends and changes in distribution. This information can provide insight towards those areas requiring management aimed at restoring native habitats and their constituent bird species. However, surveys of bird abundance alone do not fully answer questions pertaining to the viability of these populations. In addition, the variability inherent in the estimated densities of rare species can be very large and preclude assessment of trends in the near-term. In order to determine whether the resident populations are increasing, decreasing, or stable in Kahuku, demographic studies should be considered for tracking the three endangered species and for understanding their requirements for recovery.

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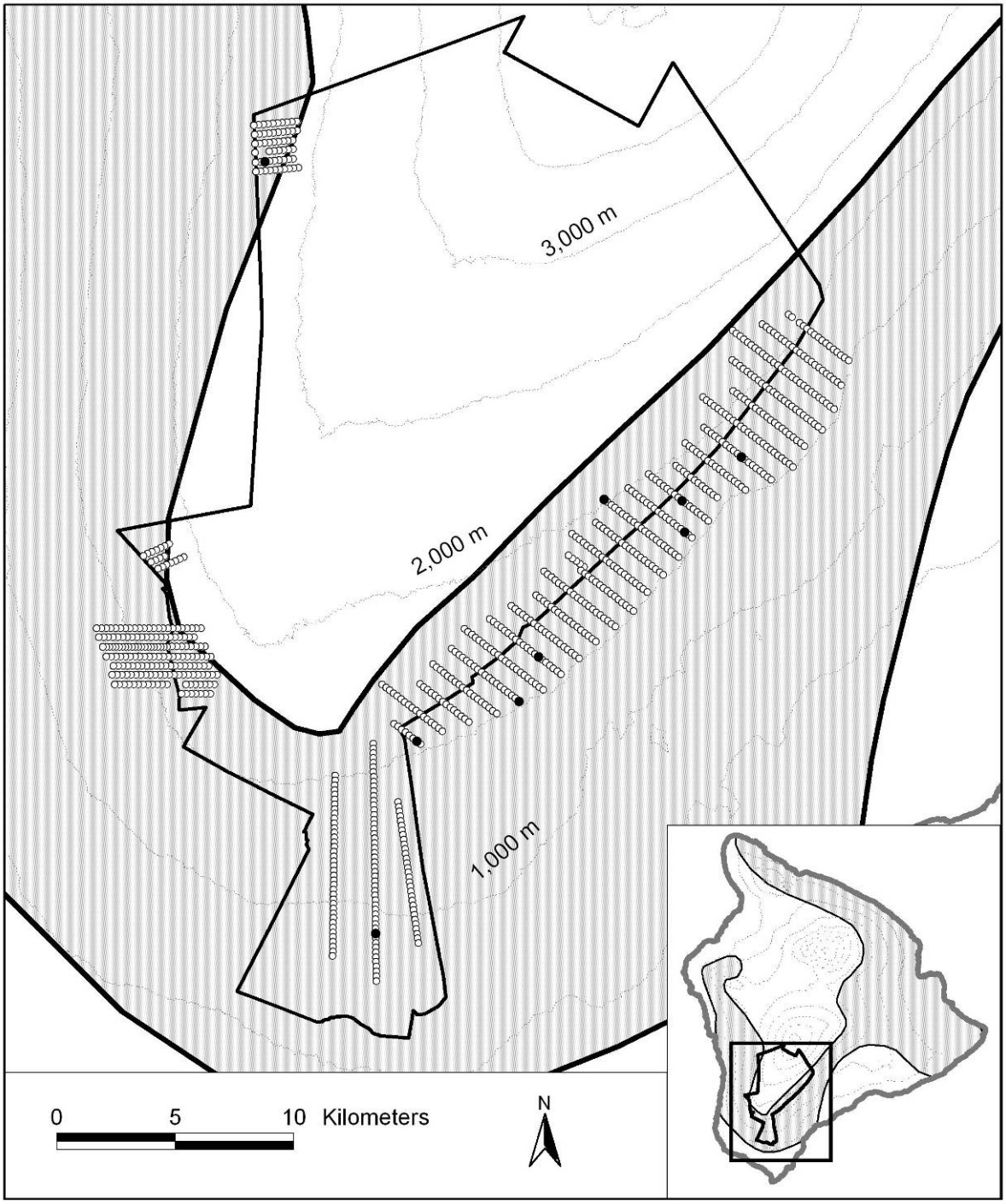

Figure 5. Hawaiian Hawk (`Io) occurrence (solid points) at survey stations in the Kahuku region of Hawai`i Island (inset). Shaded area indicates species range. Contours are in 500 m intervals.

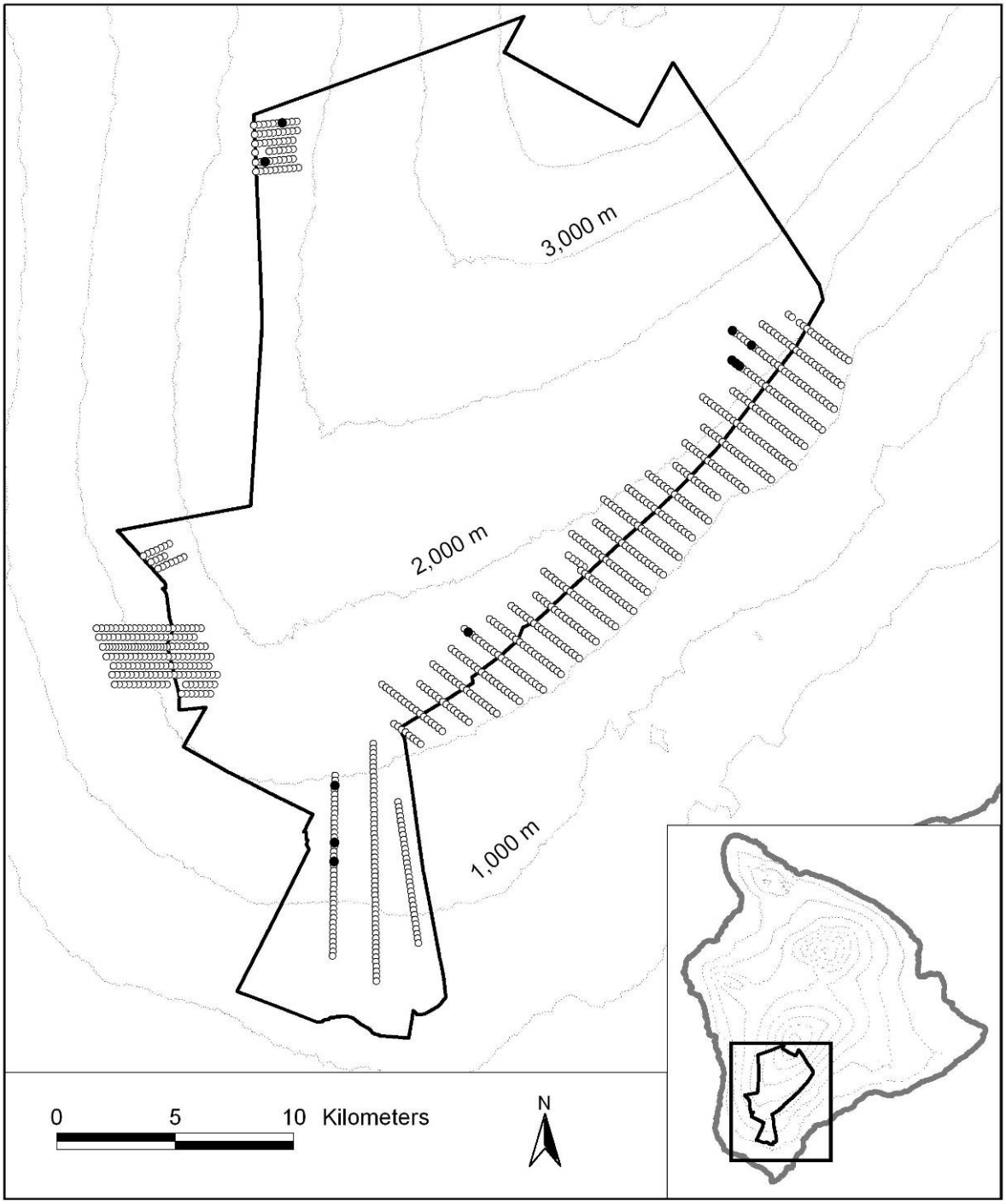

Figure 6. Pacific Golden-Plover (Kōlea) occurrence (solid points) at survey stations in the Kahuku region of Hawai`i Island (inset). Contours are in 500 m intervals.

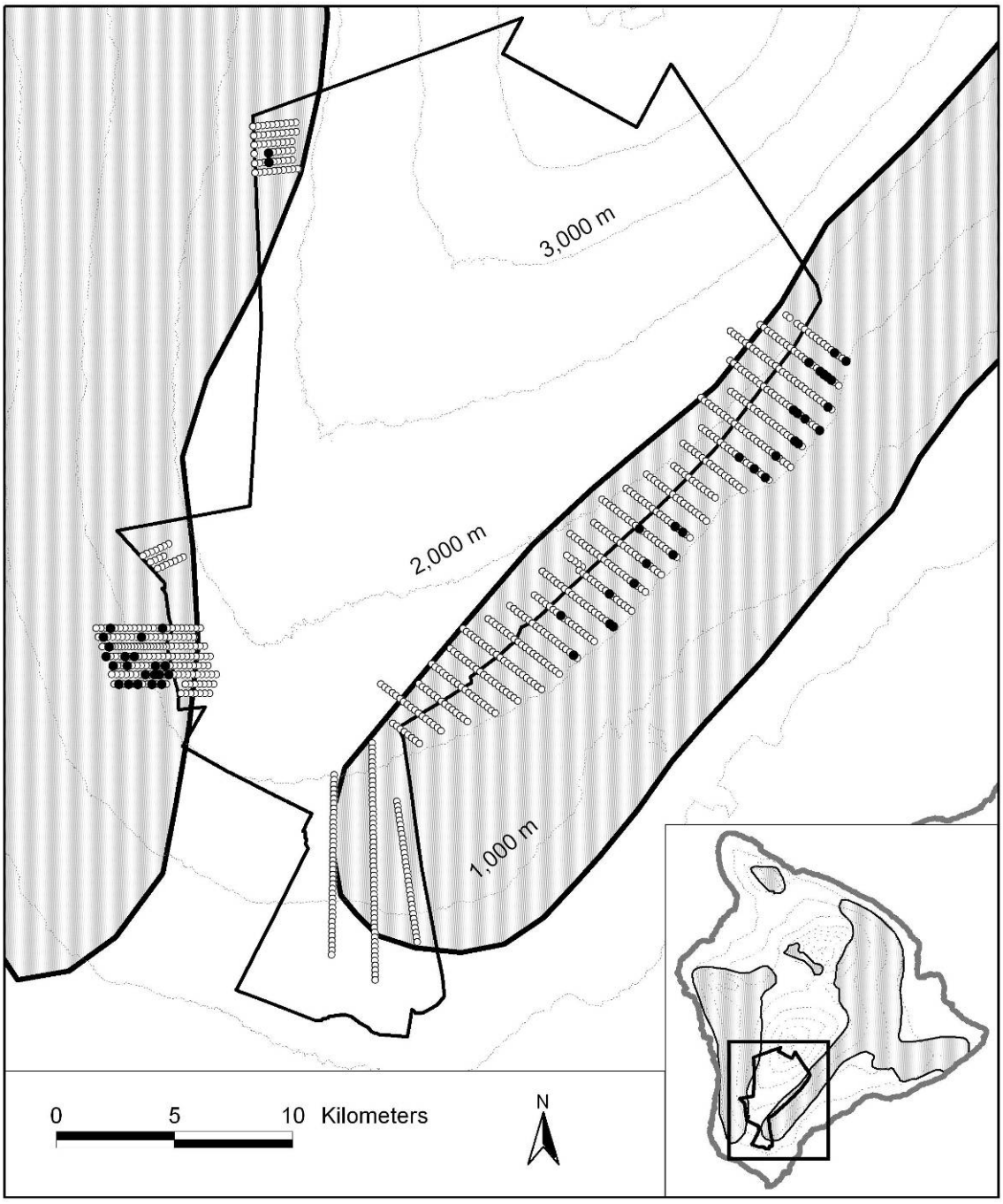

Figure 7. Hawai`i `Elepaio occurrence (solid points) at survey stations in the Kahuku region of Hawai`i Island (inset). Shaded area indicates species range. Contours are in 500 m intervals.

Figure 8. `Ōma`o occurrence (solid points) at survey stations in the Kahuku region of Hawai`i Island (inset). Shaded area indicates species range. Contours are in 500 m intervals.

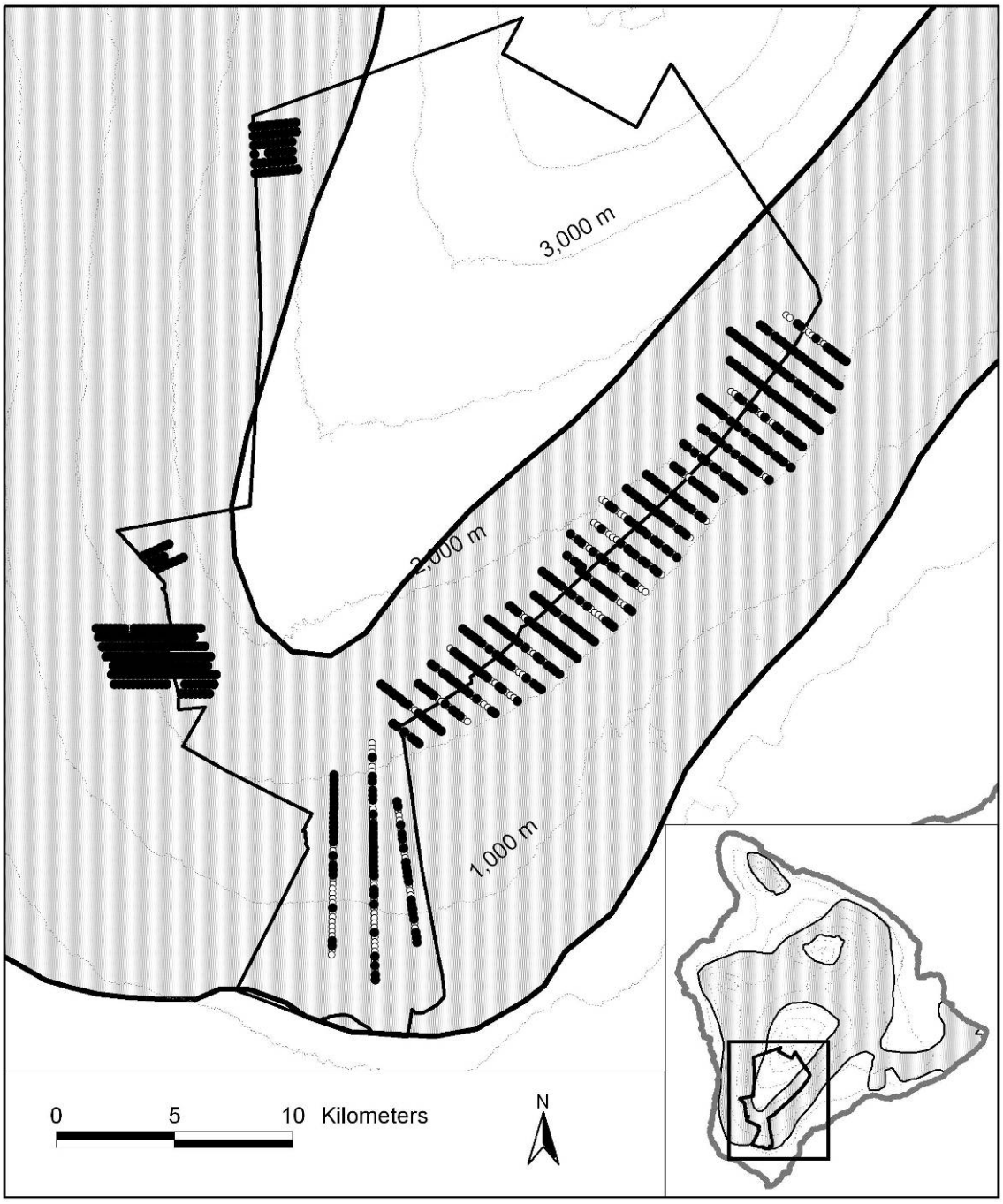

Figure 9. Hawai`i `Amakihi occurrence (solid points) at survey stations in the Kahuku region of Hawai`i Island (inset). Shaded area indicates species range. Contours are in 500 m intervals.

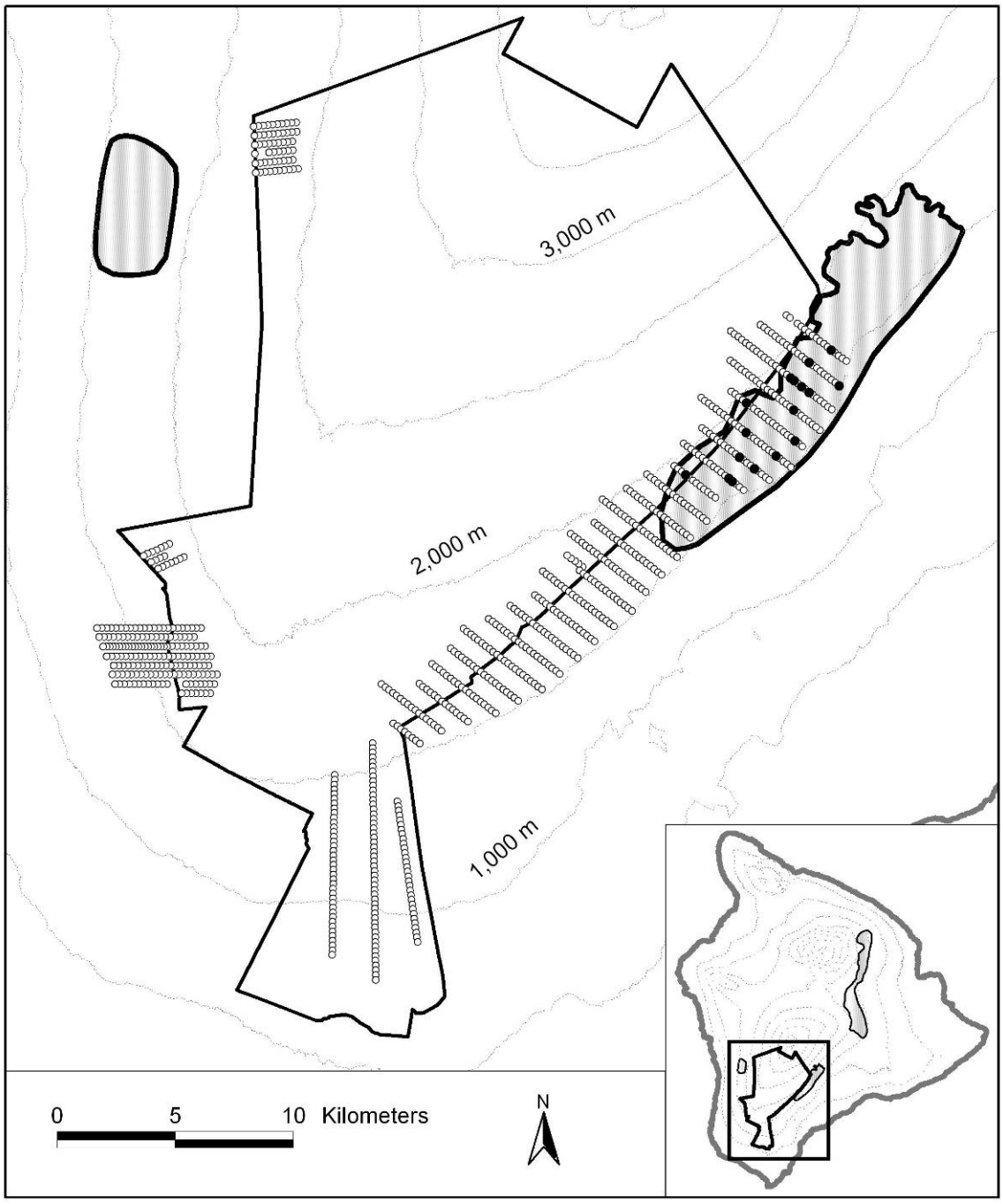

Figure 10. `Akiapōlā`au occurrence (solid points) at survey stations in the Kahuku region of Hawai`i Island (inset). Shaded area indicates species range. Contours are in 500 m intervals.

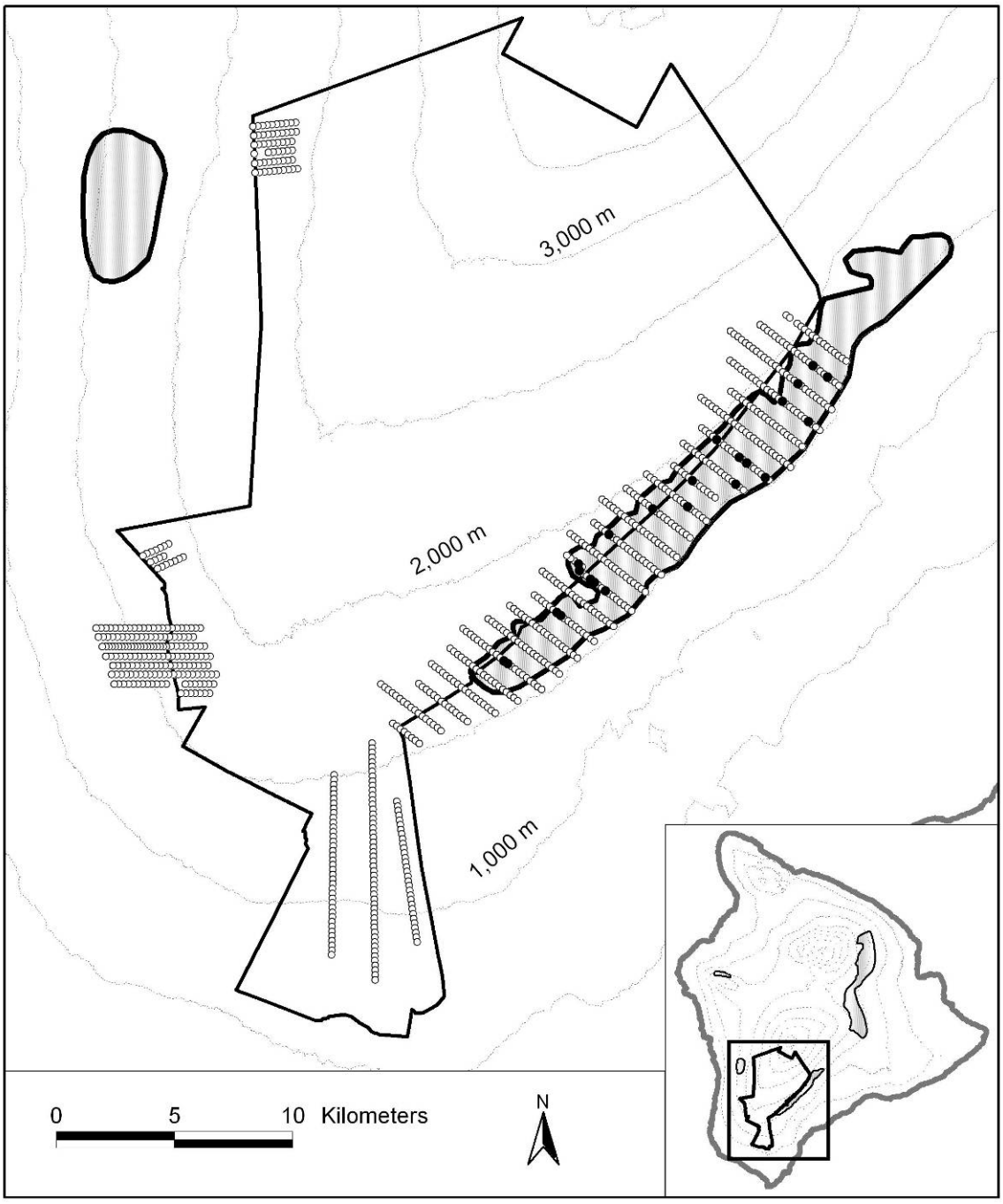

Figure 11. Hawai`i Creeper occurrence (solid points) at survey stations in the Kahuku region of Hawai`i Island (inset). Shaded area indicates species range. Contours are in 500 m intervals.

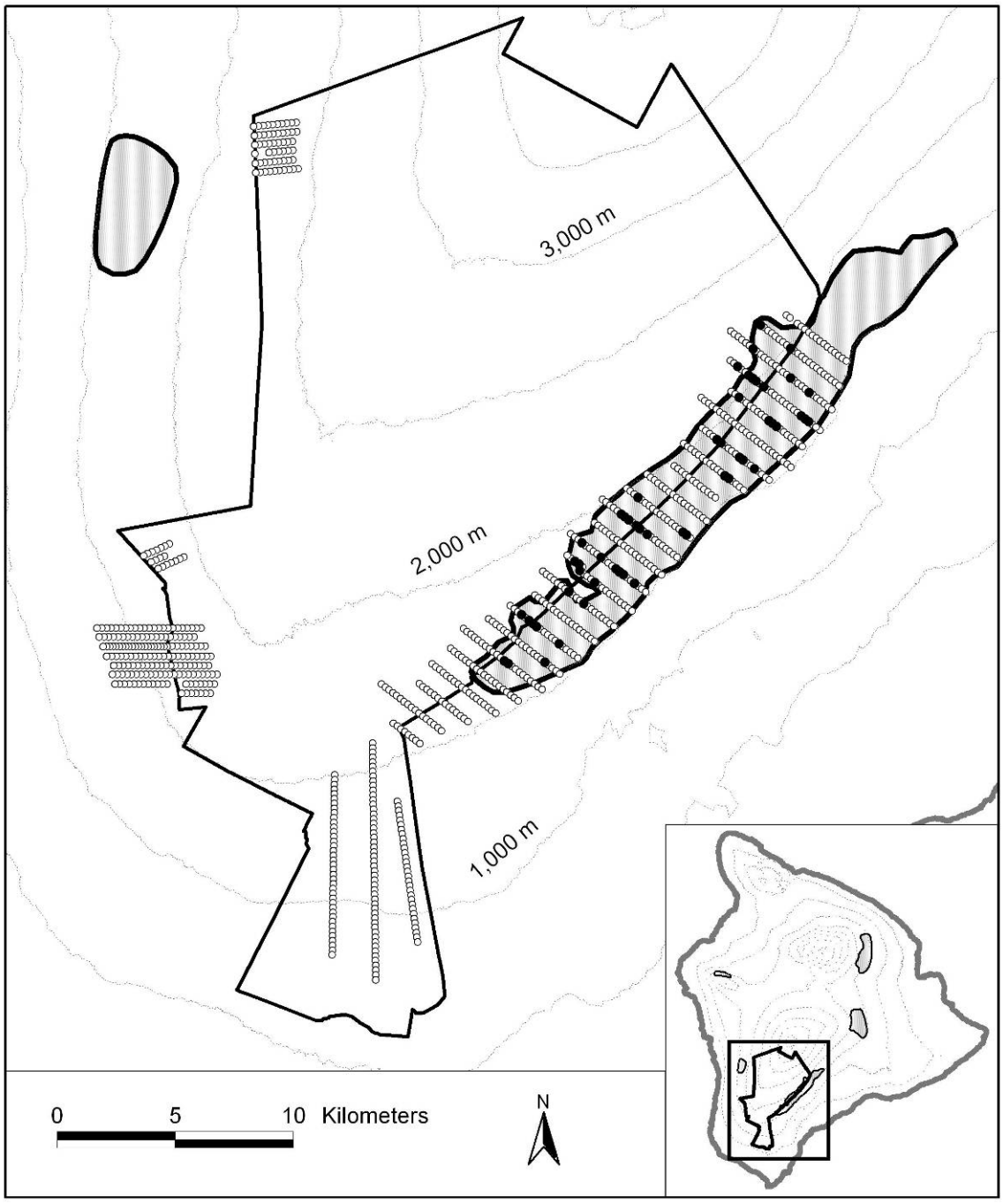

Figure 12. Hawai`i `Ākepa occurrence (solid points) at survey stations in the Kahuku region of Hawai`i Island (inset). Shaded area indicates species range. Contours are in 500 m intervals.

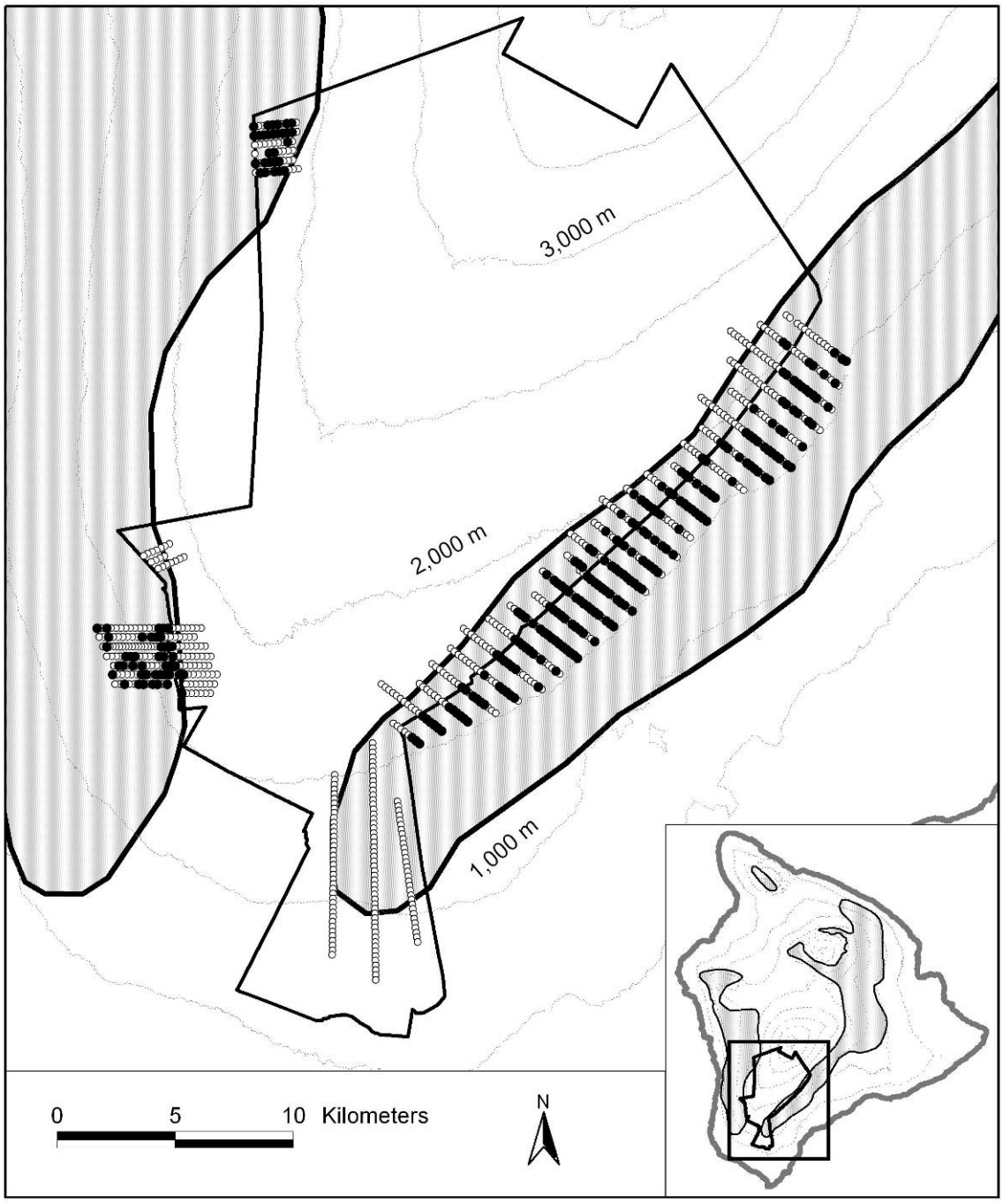

Figure 13. `I`iwi occurrence (solid points) at survey stations in the Kahuku region of Hawai`i Island (inset). Shaded area indicates species range. Contours are in 500 m intervals.

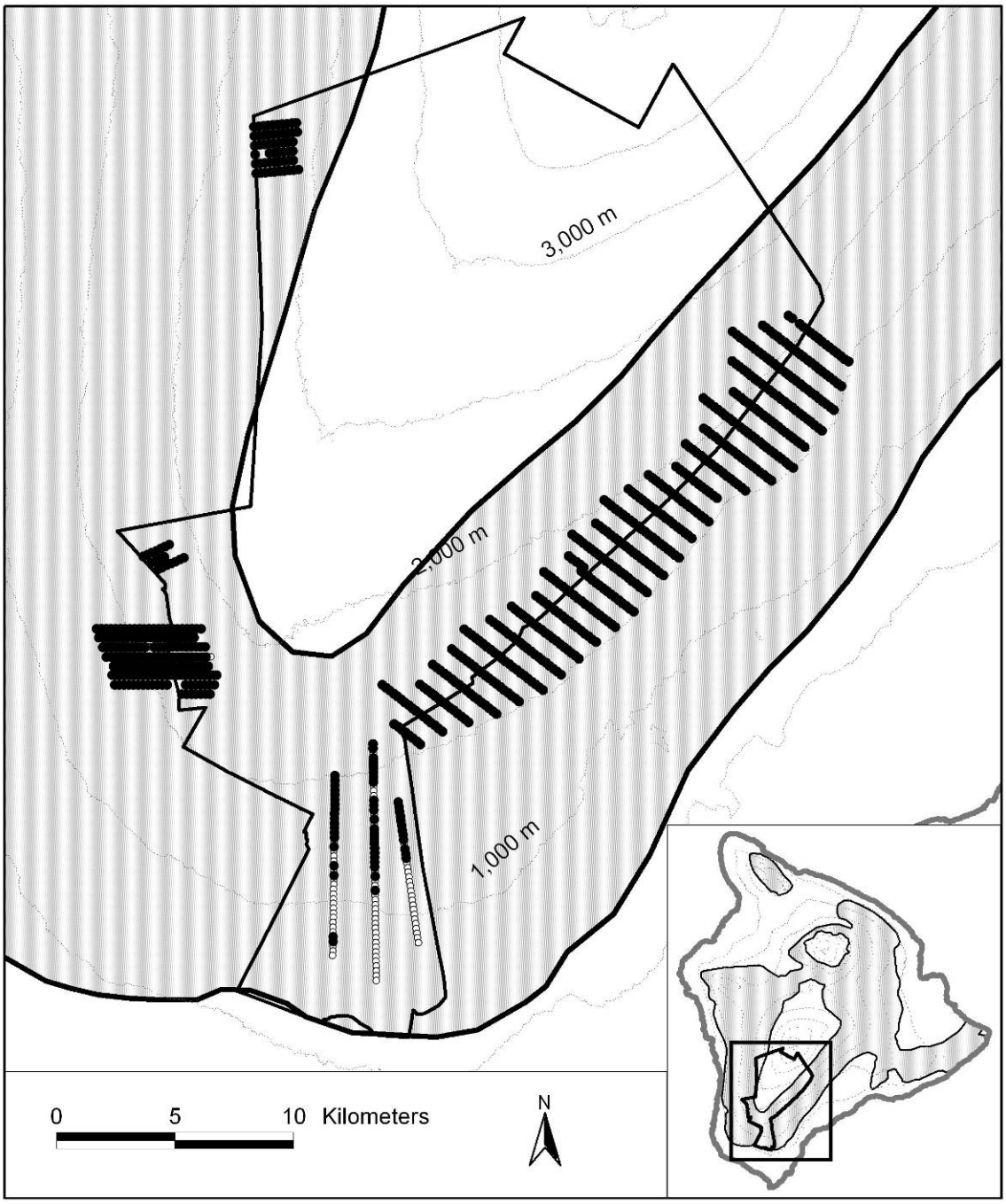

Figure 14. `Apapane occurrence (solid points) at survey stations in the Kahuku region of Hawai`i Island (inset). Shaded area indicates species range. Contours are in 500 m intervals.

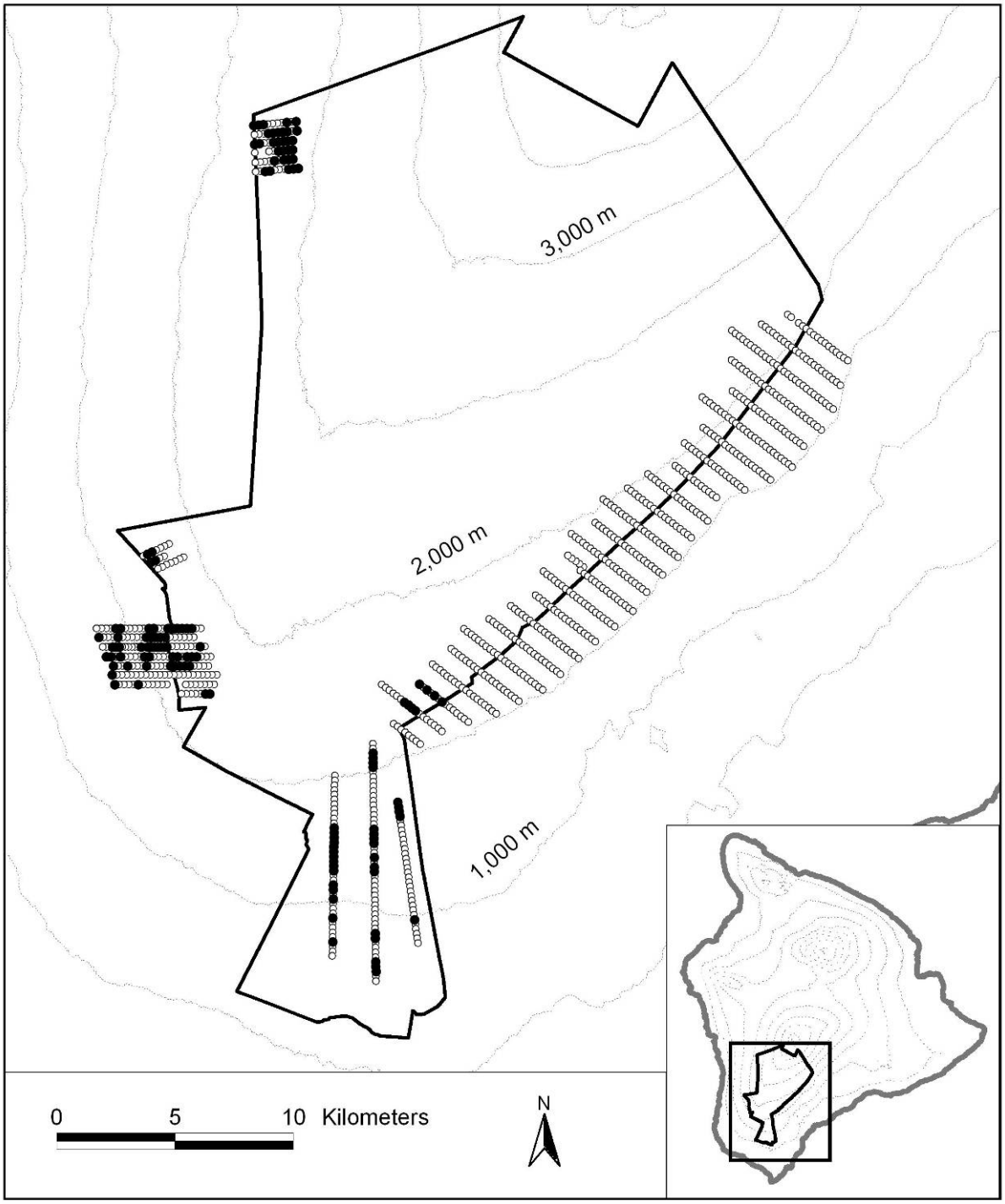

Figure 15. Erckel's Francolin occurrence (solid points) at survey stations in the Kahuku region of Hawai`i Island (inset). Contours are in 500 m intervals.

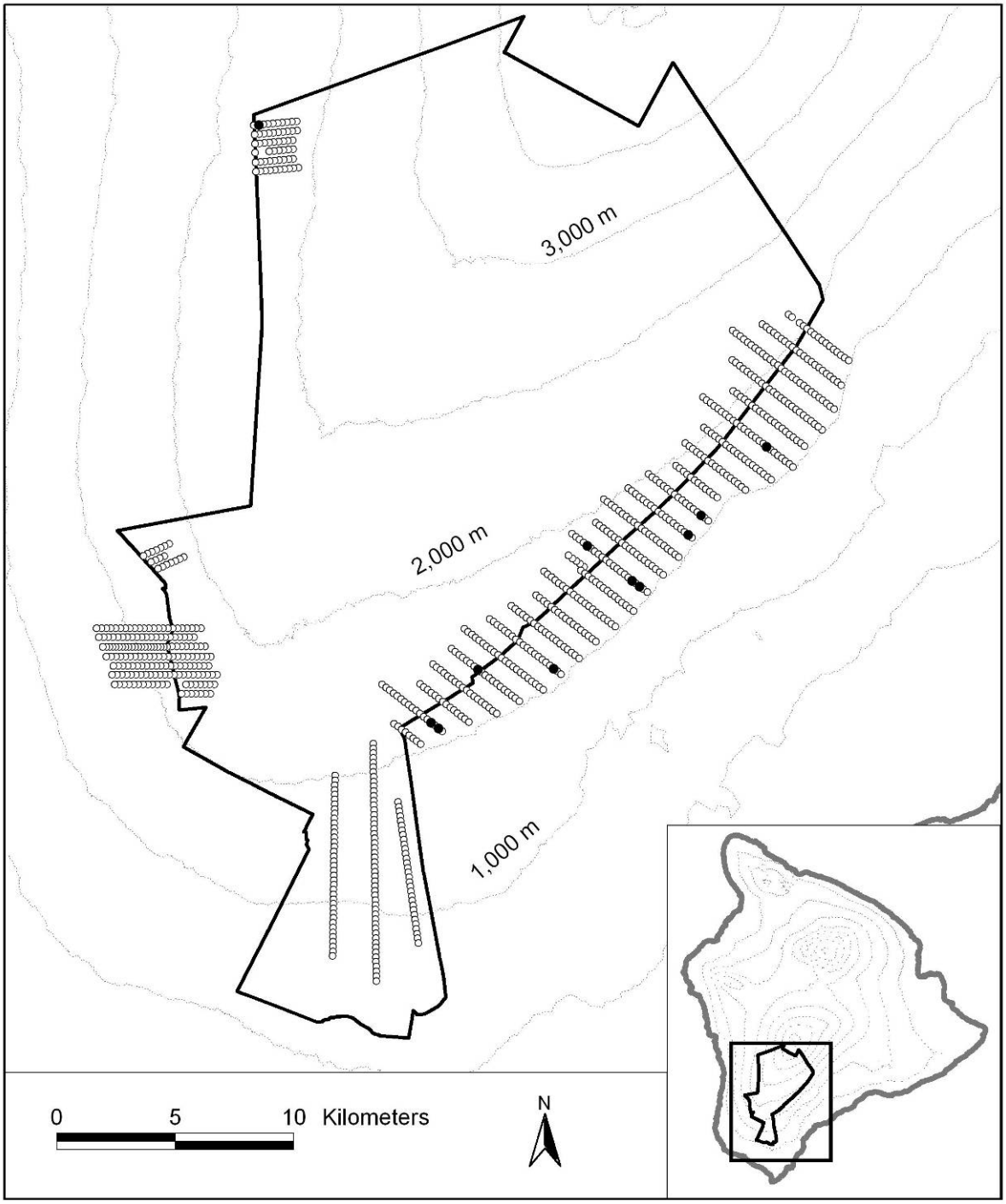

Figure 16. Kalij Pheasant occurrence (solid points) at survey stations in the Kahuku region of Hawai`i Island (inset). Contours are in 500 m intervals.

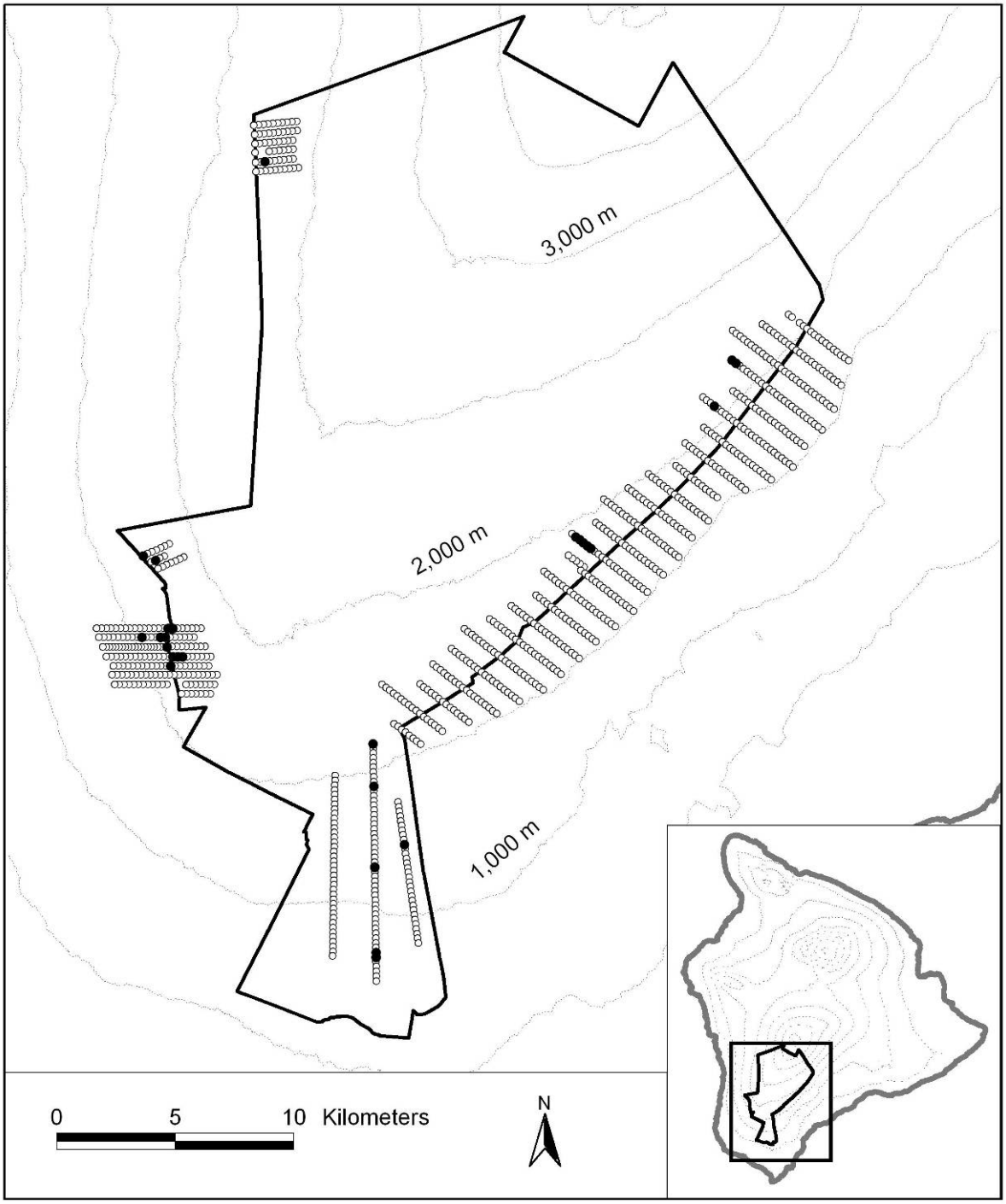

Figure 17. Wild Turkey occurrence (solid points) at survey stations in the Kahuku region of Hawai`i Island (inset). Contours are in 500 m intervals.

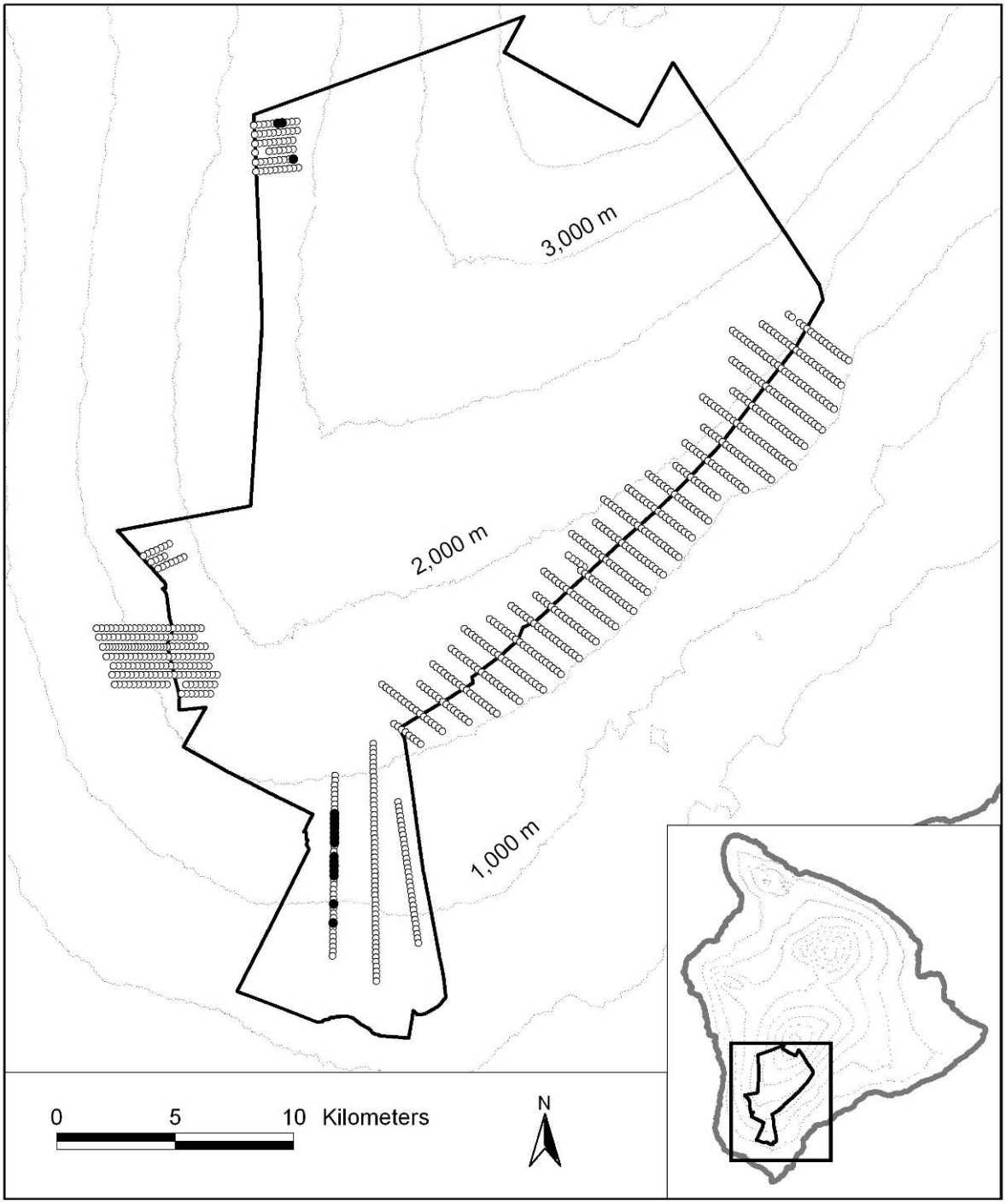

Figure 18. Spotted Dove occurrence (solid points) at survey stations in the Kahuku region of Hawai`i Island (inset). Contours are in 500 m intervals.

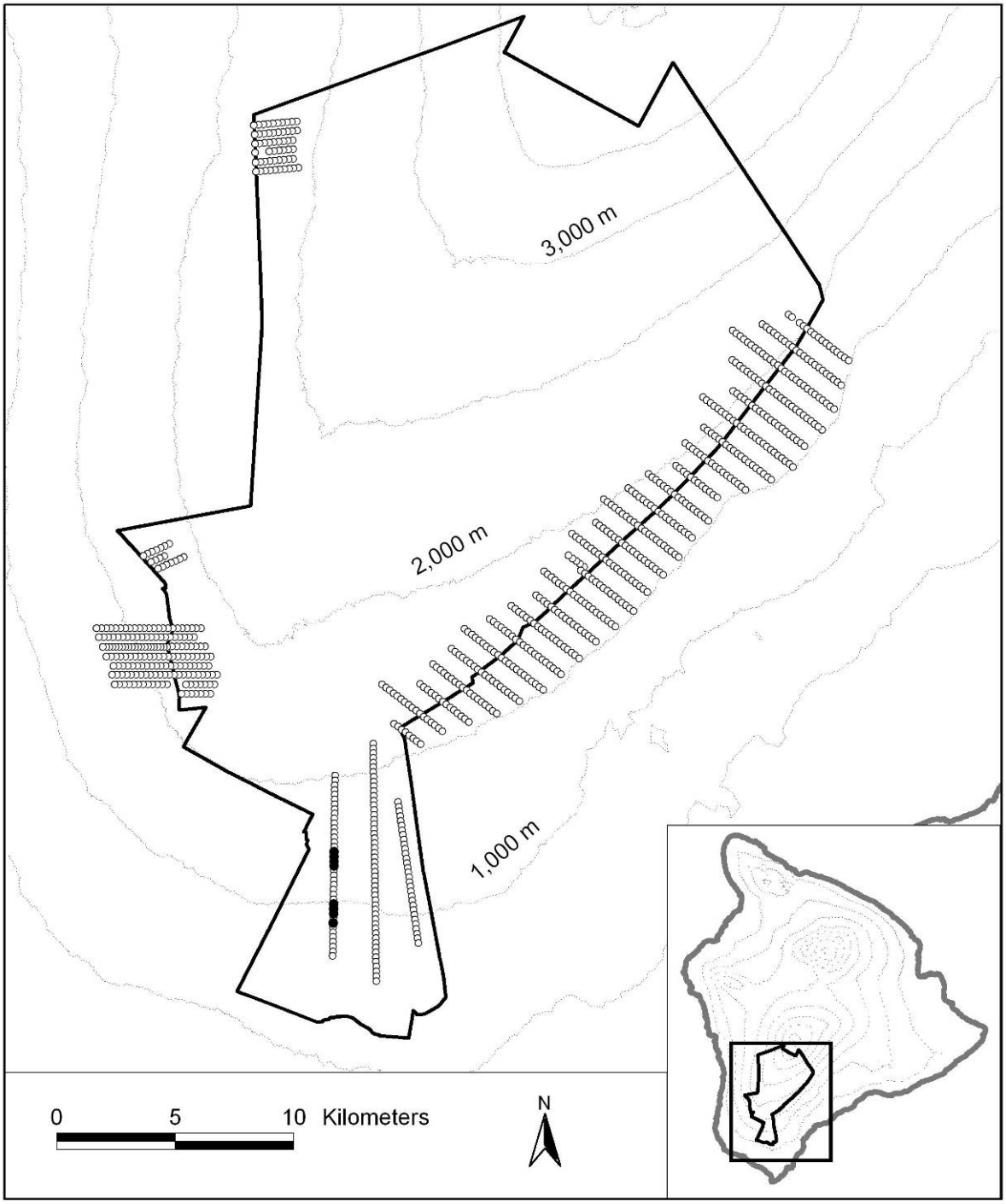

Figure 19. Zebra Dove occurrence (solid points) at survey stations in the Kahuku region of Hawai`i Island (inset). Contours are in 500 m intervals.

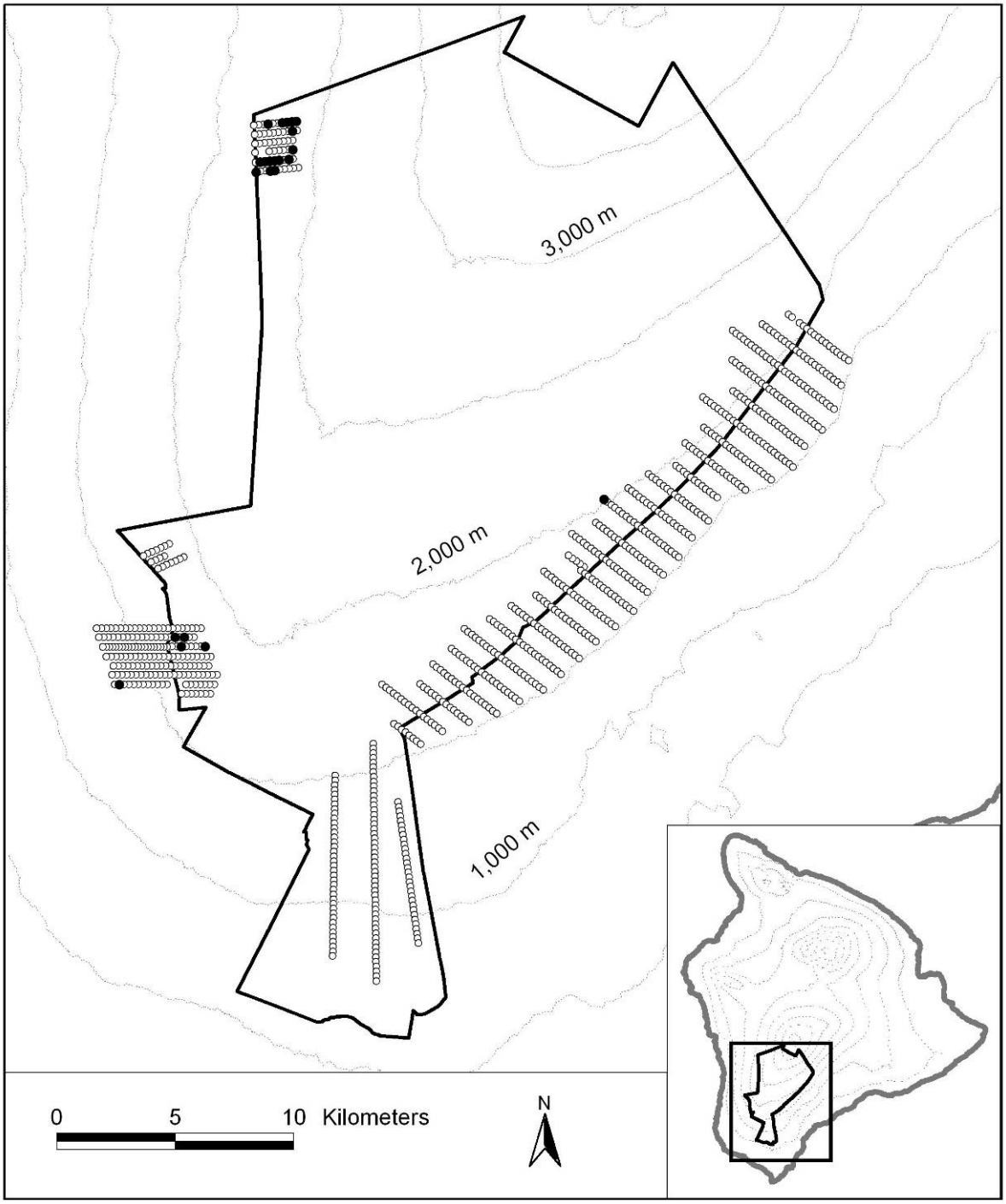

Figure 20. Sky Lark occurrence (solid points) at survey stations in the Kahuku region of Hawai`i Island (inset). Contours are in 500 m intervals.

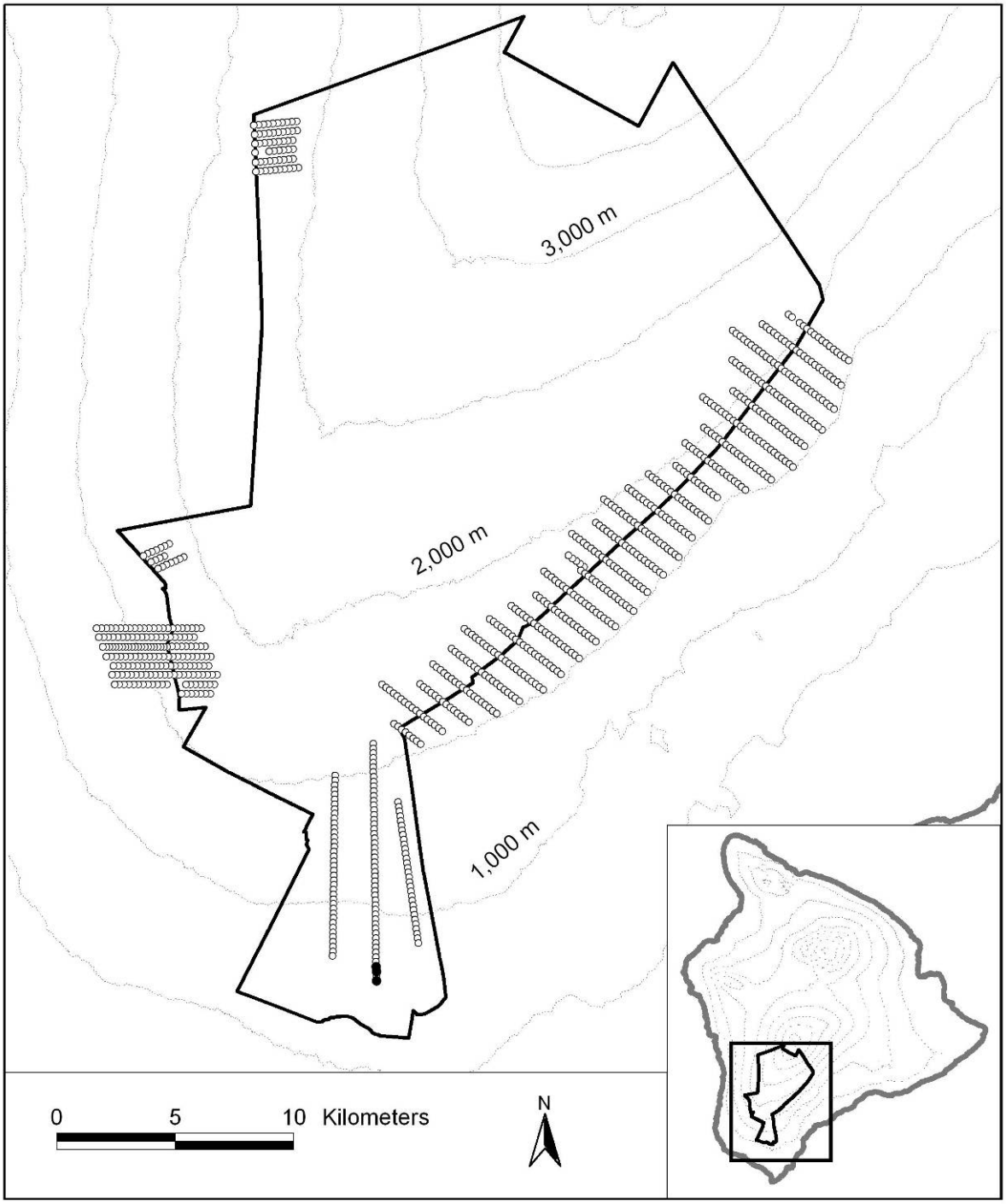

Figure 21. Hwamei occurrence (solid points) at survey stations in the Kahuku region of Hawai`i Island (inset). Contours are in 500 m intervals.

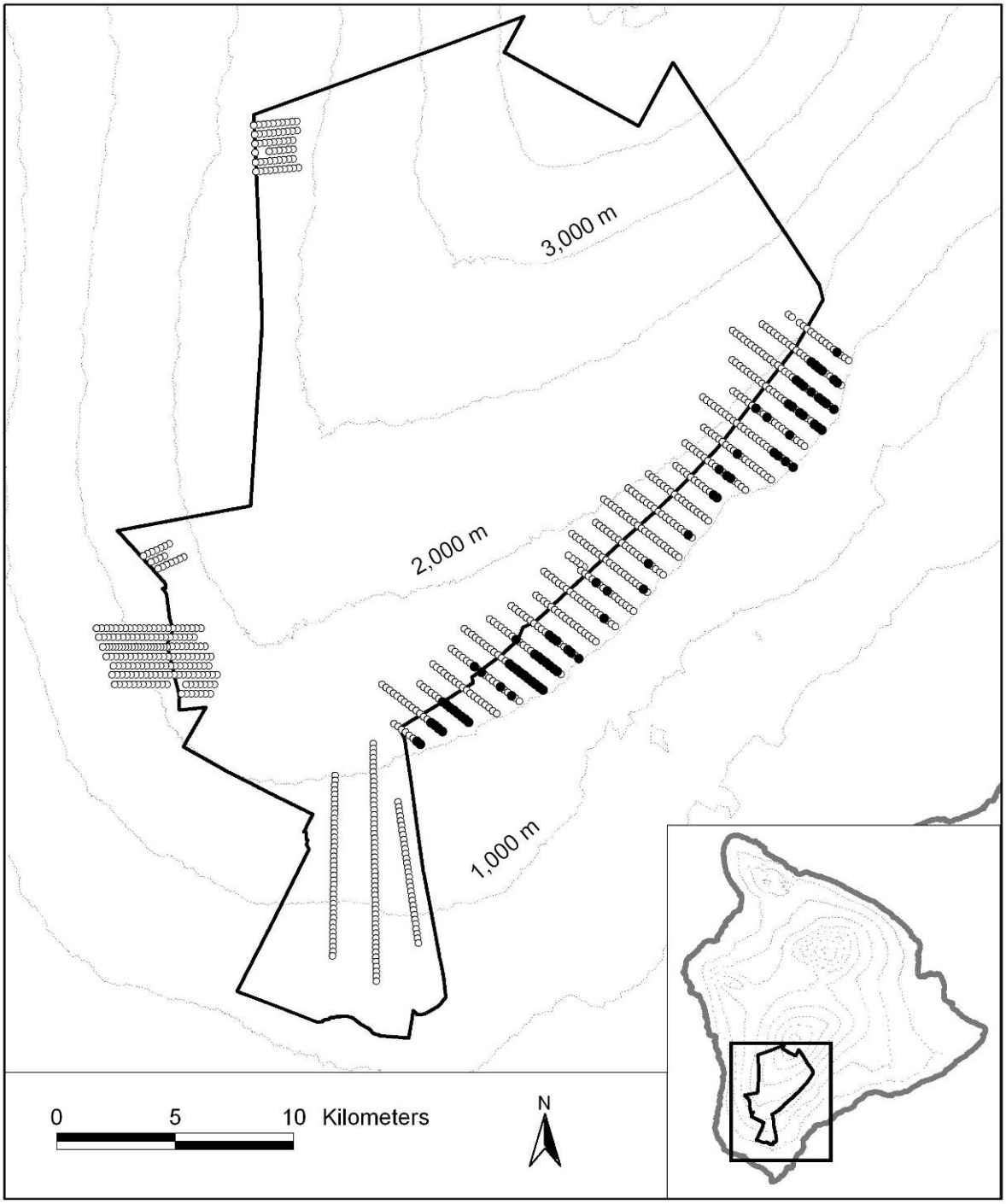

Figure 22. Red-billed Leiothrix occurrence (solid points) at survey stations in the Kahuku region of Hawai`i Island (inset). Contours are in 500 m intervals.

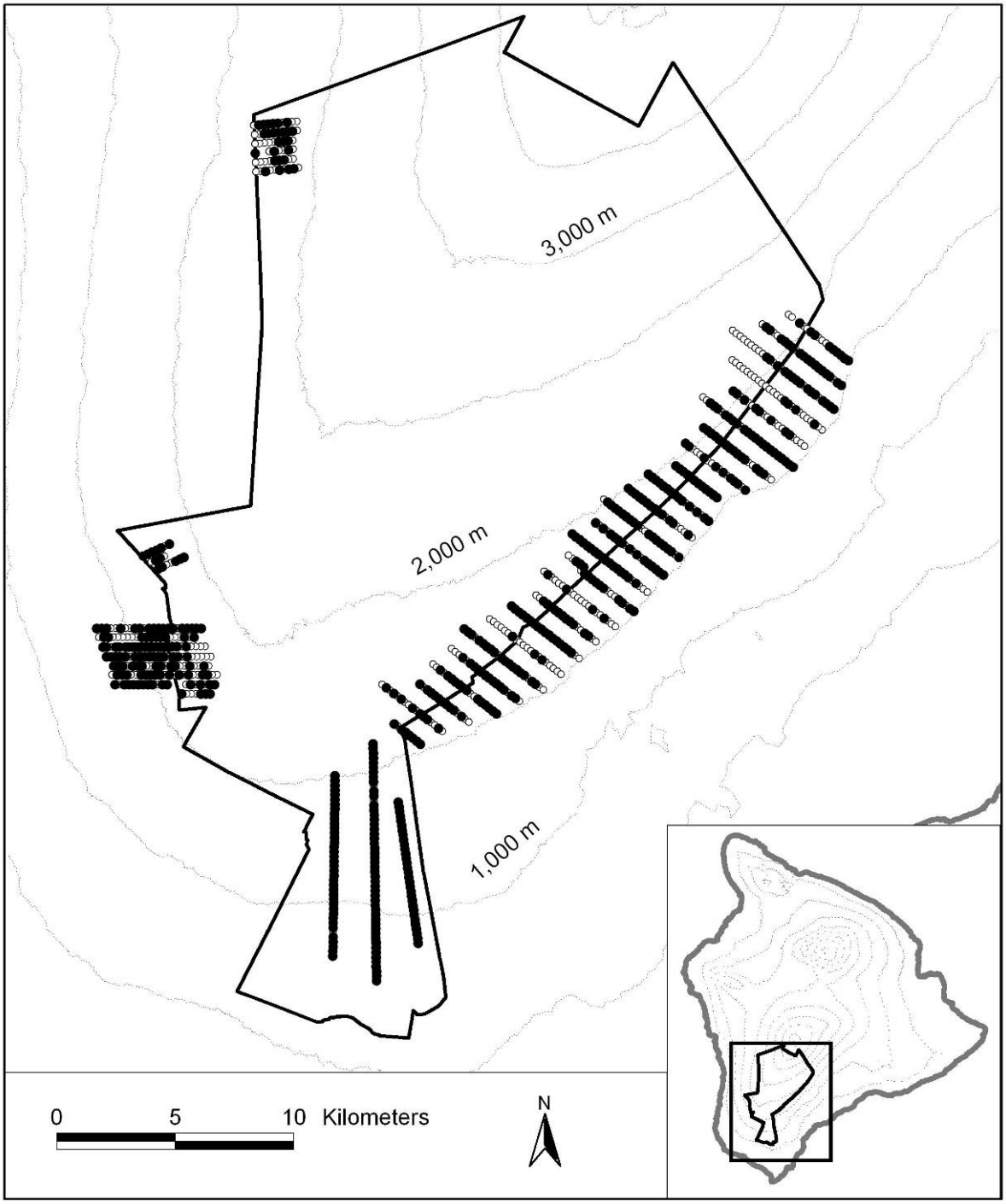

Figure 23. Japanese White-eye occurrence (solid points) at survey stations in the Kahuku region of Hawai`i Island (inset). Contours are in 500 m intervals.

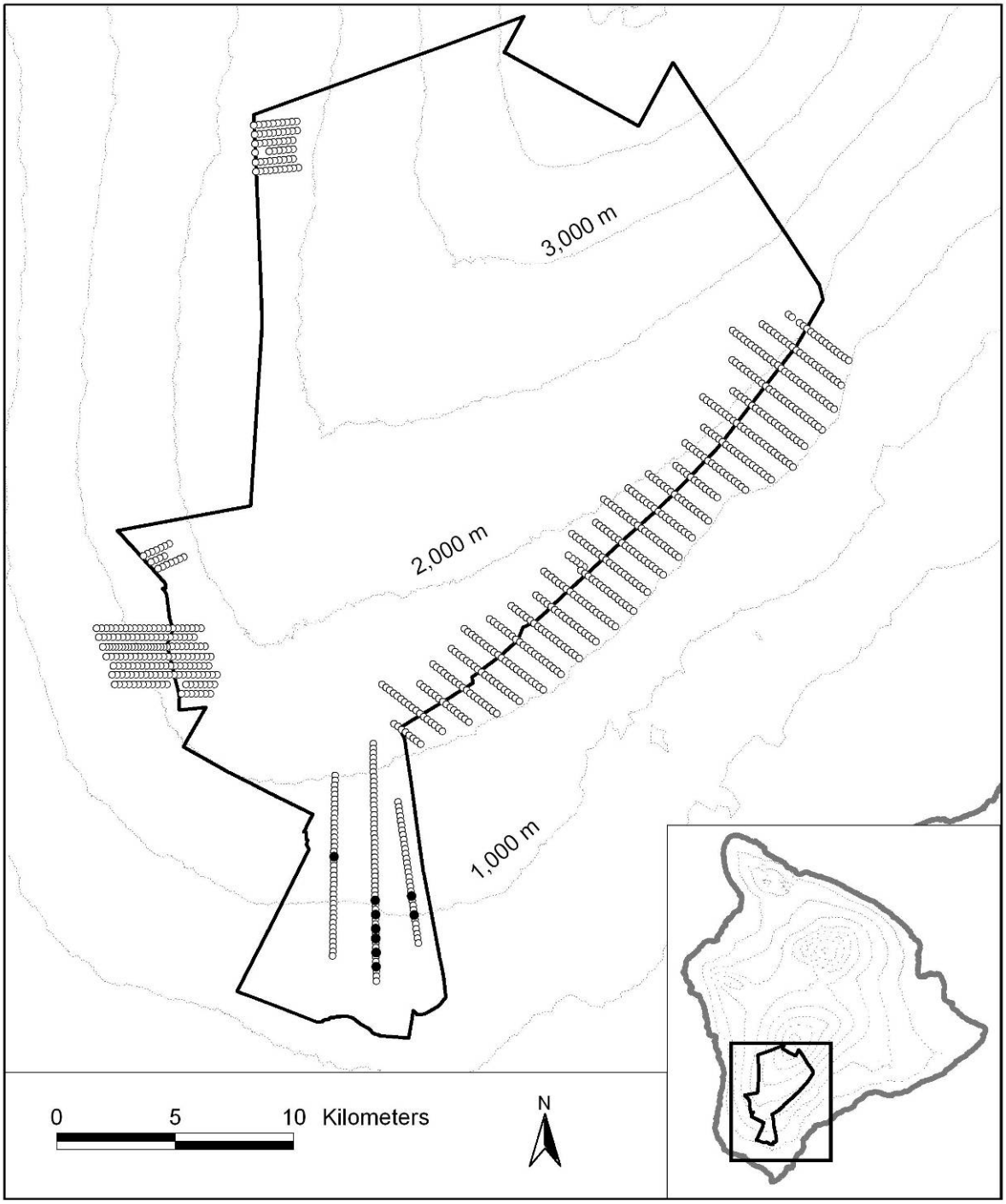

Figure 24. Common Myna occurrence (solid points) at survey stations in the Kahuku region of Hawai`i Island (inset). Contours are in 500 m intervals.

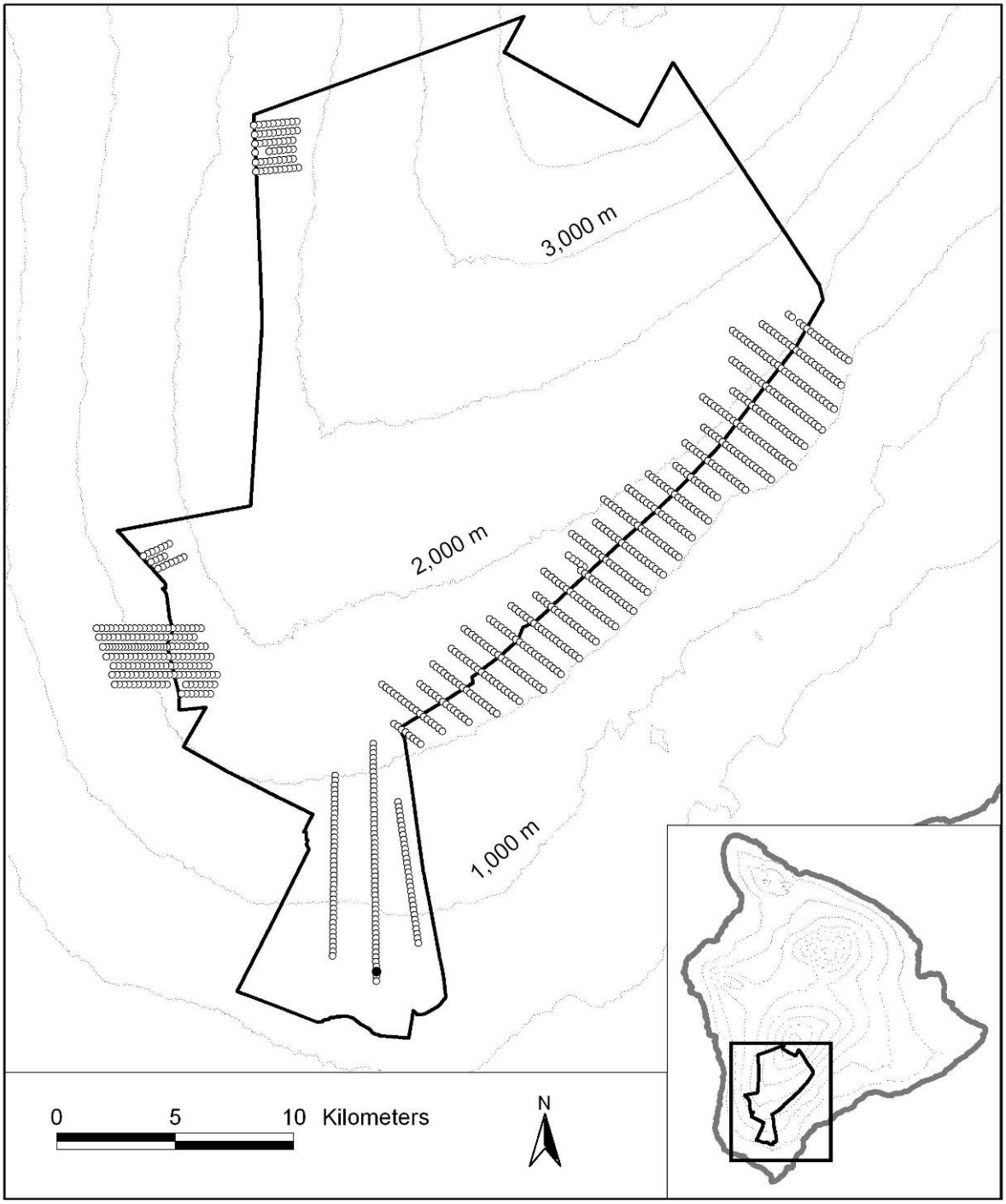

Figure 25. Saffron Finch occurrence (solid points) at survey stations in the Kahuku region of Hawai`i Island (inset). Contours are in 500 m intervals.

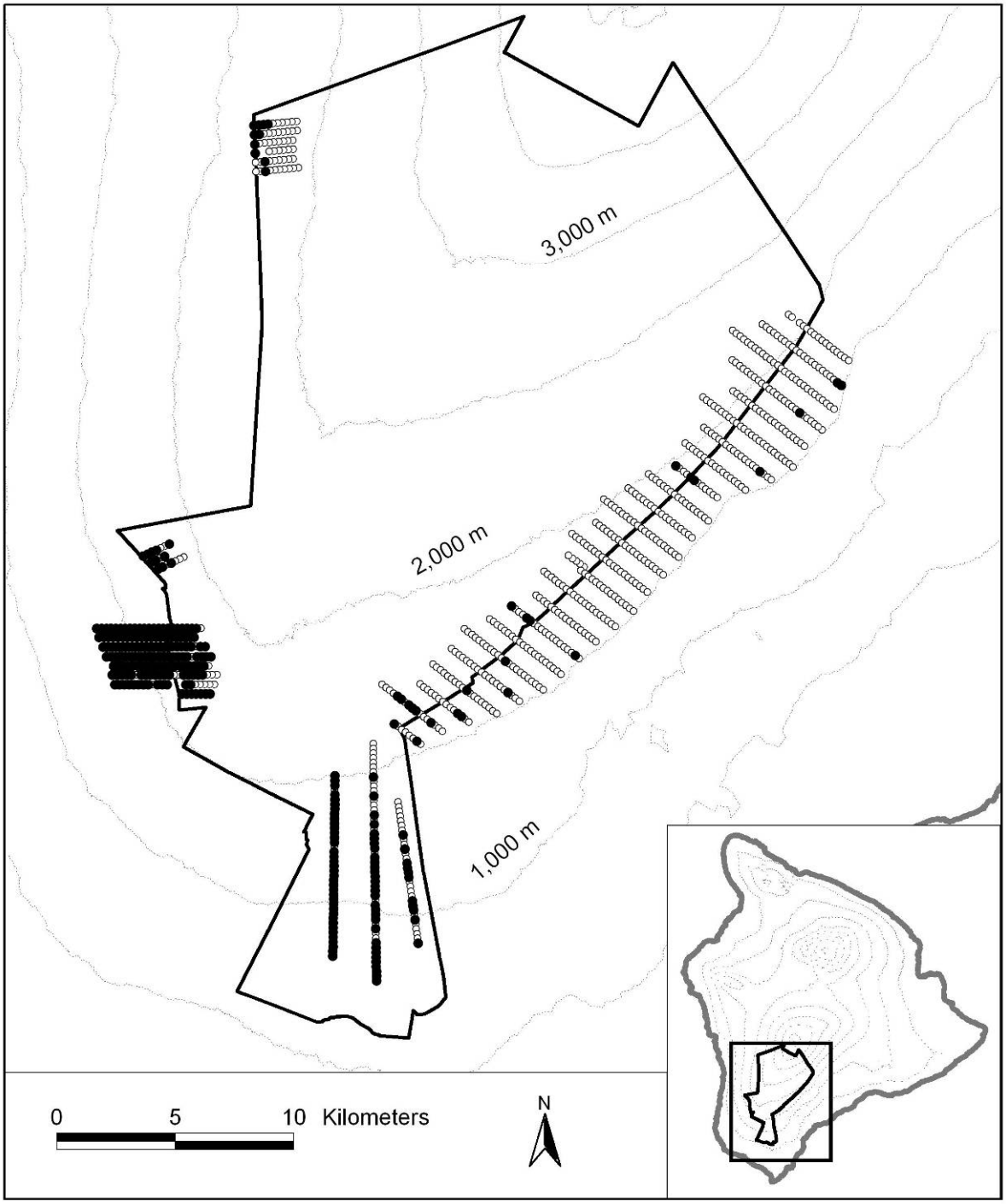

Figure 26. Northern Cardinal occurrence (solid points) at survey stations in the Kahuku region of Hawai`i Island (inset). Contours are in 500 m intervals.

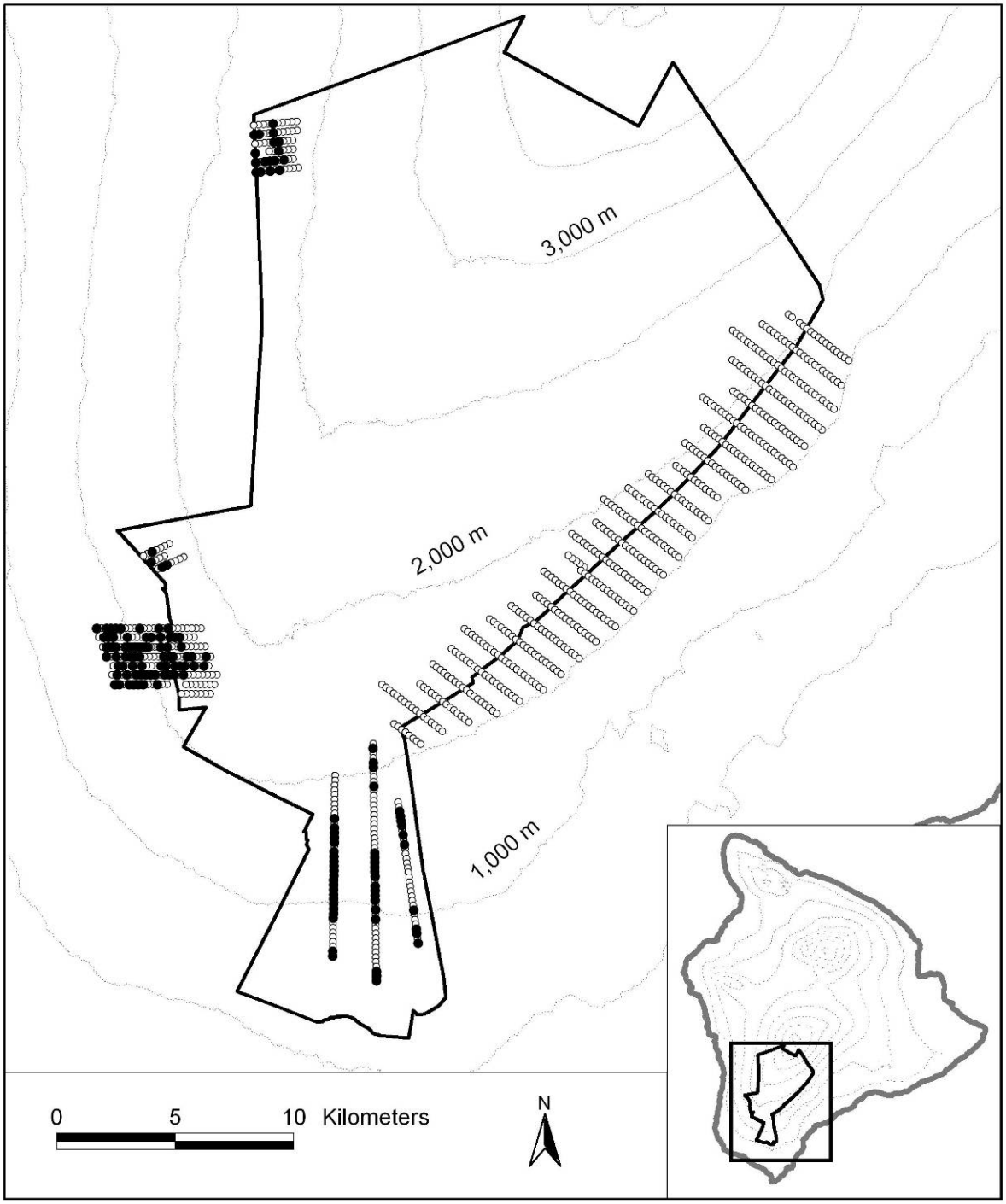

Figure 27. House Finch occurrence (solid points) at survey stations in the Kahuku region of Hawai`i Island (inset). Contours are in 500 m intervals.

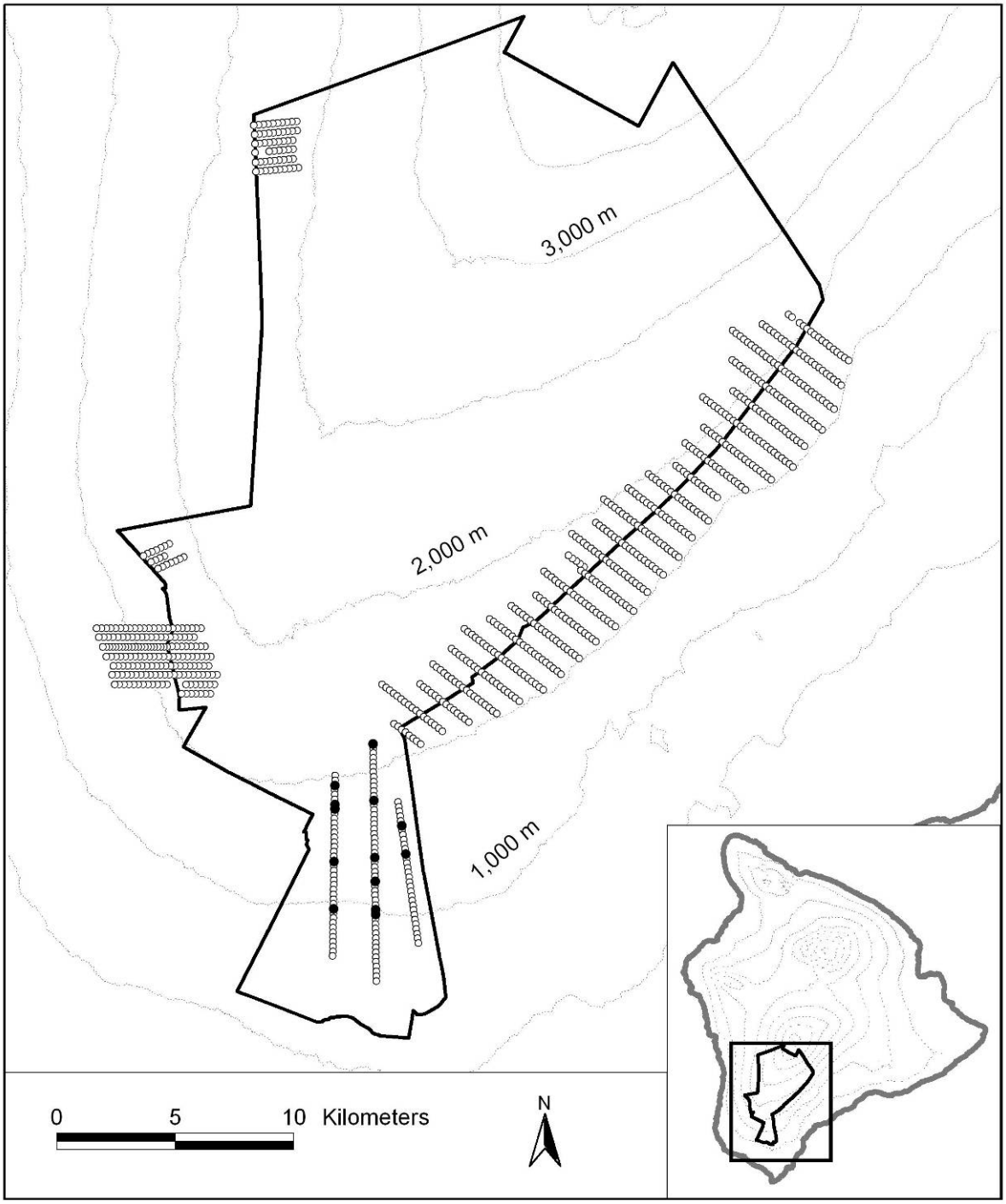

Figure 28. Yellow-fronted Canary occurrence (solid points) at survey stations in the Kahuku region of Hawai`i Island (inset). Contours are in 500 m intervals.

APPENDIX A. BIRD DETECTION MODEL PARAMETERS FROM THE PROGRAM DISTANCE FOR THE KAHUKU STUDY AREA

Parameters for the final model used to estimate population densities for each species includes the truncation distance, key function, covariates, and effective area sampled (i.e., detection radius). Species are ordered taxonomically within native and alien categories.

Native Species	Truncation	Key Function	Covariates	Detection radius
Hawai'i 'Elepaio	48.0 m	H-norm	month	34.6 m
'Ōma'o	89.8 m	H-norm	observer	59.3 m
Hawai'i 'Amakihi	67.0 m	H-rate	observer & wind	54.0 m
'Akiapōlā'au	86.0 m	H-norm	cloud	52.0 m
Hawai'i Creeper	56.0 m	H-norm	none	31.2 m
Hawai'i 'Ākepa	52.7 m	H-rate	none	43.5 m
'I'iwi	65.2 m	H-rate	none	48.9 m
'Apapane	59.0 m	H-rate	observer, gust & time	48.3 m
Non-native Species				
Erckel's Francolin	136 m	H-rate	gust	111.1 m
Kalij Pheasant	70.0 m	H-norm	none	38.7 m
Wild Turkey	190.0 m	H-rate	none	114.0 m
Spotted Dove	143.0 m	H-rate	none	119.4 m
Sky Lark	126.0 m	H-rate	none	106.1 m
Red-billed Leiothrix	73.6 m	H-rate	year, gust & wind	52.3 m
Japanese White-eye	50.4 m	H-rate	year, observer, cloud, gust & wind	30.2 m
Northern Cardinal	107.0 m	H-norm	none	89.3 m
House Finch	70.6 m	H-rate	none	53.9 m
Yellow-fronted Canary	71.0 m	H-norm	none	34.0 m

APPENDIX B. UPDATED SPECIES LIST FOR THE KAHUKU UNIT OF HAWAI`I VOLCANOES NATIONAL PARK BASED ON THE 2005 SURVEY

Species are arranged taxonomically in accordance with the American Ornithologists' Union checklist (1998).

Common Name	Species Name	Family	Abundance	Residency	Nativity
Hawaiian Goose (Nēnē)	*Branta sandvicensis*	Anatidae	Uncommon	Breeder	Native
Hawaiian Hawk (`Io)	*Buteo solitarius*	Accipitridae	Common	Breeder	Native
Chukar	*Alectoris chukar*	Phasianidae	Uncommon	Breeder	Non-Native
Black Francolin	*Francolinus francolinus*	Phasianidae	Extirpated?	unknown	Non-Native
Erckel's Francolin	*Francolinus erckelii*	Phasianidae	Common	Breeder	Non-Native
Japanese Quail	*Coturnix japonica*	Phasianidae	Extirpated?	unknown	Non-Native
Kalij Pheasant	*Lophura leucomelanos*	Phasianidae	Common	Breeder	Non-Native
Ring-necked Pheasant	*Phasianus colchicus*	Phasianidae	Extirpated?	unknown	Non-Native
Common Peafowl	*Pavo cristatus*	Phasianidae	Uncommon	Breeder	Non-Native
Wild Turkey	*Meleagris gallopavo*	Phasianidae	Common	Breeder	Non-Native
Pacific Golden-Plover (Kōlea)	*Pluvialis fulva*	Charadriidae	Uncommon	Migrant	Native
Rock Dove	*Columba livia*	Columbidae	Uncommon	Breeder	Non-Native
Spotted Dove	*Streptopelia chinensis*	Columbidae	Uncommon	Breeder	Non-Native
Zebra Dove	*Geopelia striata*	Columbidae	Uncommon	Breeder	Non-Native
Hawaiian (Short-eared) Owl (Pueo)	*Asio flammeus sandwichensis*	Strigidae	Uncommon	Breeder	Native
Hawai`i `Elepaio	*Chasiempis sandwichensis*	Monarchidae	Common	Breeder	Native
(Eurasian) Sky Lark	*Alauda arvensis*	Alaudidae	Uncommon	Breeder	Non-Native
`Ōma`o	*Myadestes obscurus*	Turdidae	Abundant	Breeder	Native
Hwamei	*Garrulax canorus*	Timaliidae	Common	Breeder	Non-Native
Red-billed Leiothrix	*Leiothrix lutea*	Timaliidae	Common	Breeder	Non-Native
Japanese White-eye	*Zosterops japonicus*	Zosteropidae	Abundant	Breeder	Non-Native
Common Myna	*Acridotheres tristis*	Sturnidae	Uncommon	Breeder	Non-Native
Saffron Finch	*Sicalis flaveola*	Emberizidae	Uncommon	Breeder	Non-Native
Yellow-billed Cardinal	*Paroria capitata*	Emberizidae	Rare	unknown	Non-Native
Northern Cardinal	*Cardinalis cardinalis*	Cardinalidae	Common	Breeder	Non-Native
House Finch	*Carpodacus mexicanus*	Fringillidae	Common	Breeder	Non-Native
Yellow-fronted Canary	*Serinus mozambicus*	Fringillidae	Uncommon	Breeder	Non-Native
Hawai`i `Amakihi	*Hemignathus virens virens*	Fringillidae	Abundant	Breeder	Native

Common Name	Species Name	Family	Abundance	Residency	Nativity
`Akiapōlā`au	*Hemignathus munroi*	Fringillidae	Rare	Breeder	Native
Hawai`i Creeper	*Oreomystis mana*	Fringillidae	Rare	Breeder	Native
Hawai`i `Ākepa	*Loxops coccineus coccineus*	Fringillidae	Rare	Breeder	Native
`I`iwi	*Vestiaria coccinea*	Fringillidae	Common	Breeder	Native
`Apapane	*Himatione sanguinea sanguinea*	Fringillidae	Abundant	Breeder	Native
Nutmeg Mannikin	*Lonchura punctulata*	Estrildidae	Common?	Breeder	Non-Native